UNIVERSITY OF PENNSYLVANIA

AN INVESTIGATION OF THE WRITTEN EXAMINATION AS A MEASURE OF ACHIEVEMENT WITH PARTICULAR REFERENCE TO GENERAL SCIENCE

JOSEPH BARDY

A THESIS

IN EDUCATION

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL OF THE UNIVERSITY OF PENNSYLVANIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

PHILADELPHIA

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PREFACE

It is impossible to acknowledge adequately my indebtedness to others in this investigation. The Seminar in Secondary Education at the University of Pennsylvania helped to solve many difficulties. Dr. E. D. Grizzell made a number of valuable suggestions. The high school principals and teachers who cooperated in the questionnaire phase of the work gave material assistance. However, the chief obligation is to Dr. A. J. Jones, Professor of Secondary Education, for his encouragement, stimulating criticism and help during the entire progress of the study.

J. B.

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CHAPTER I

INTRODUCTION

Importance of the Problem

Education may be summed up as the production and prevention of changes in human beings. In proportion as our measurements of their amounts become refined and precise, and evaluated in terms of definable products will the teaching process become scientific and efficient. This means an analysis of the products of instruction into their fundamental elements and objective gauging of their extent quantitatively comparable in nature to that prevailing in the physical sciences.

The relatively short test given at certain intervals during the semester and the longer, more formidable one held at the end of the term are probably the most important means by which achievement is measured. The results of these performances in the high school largely influence the career of the students. The marks given play a prominent part in determining success or failure in a course, the final grades, advancement from class to class, elimination from high school, academic honors, scholarships, graduation and admission to higher institutions. It is evident, therefore, that the construction and grading of written work is of vital concern both to the educator, the measurer, and to the learner, the measured.

Are the methods now used satisfactory? What is the evidence upon which a judgment can be based? The percentage of failures in examinations has an important bearing on the problem. Hopkins tabulated the distribution of marks assigned by the College Entrance Examination Board for the years 1902 to 1920 inclusive and he found the following condition:

"If all of the marks assigned in all subjects from 1902 to 1920 inclusive were combined into one grand total average distribution it would be as follows:

Grand Total.....	90–100	75–89	60–74	50–59	0–49
445,620	4.78%	18.34%	31.14%	13.78%	31.96%

In other words out of 445,620 cases, only 4.78% received the highest grade while 31.96% failed."[1]

What is the cause of this? Can it be that so few were worthy of the highest grade or that so many deserved to fail? Or might it have been due in part at least to the unreliability of the methods of testing used and the unreliability of the marking? Upon the second point there is abundant evidence.

One of the earliest studies of the reliability of teachers' marks was made in 1889 by F. Y. Edgeworth. He inserted a specimen of Latin prose composition in the English Journal of Education accompanied by a request that experienced examiners grade the paper. Twenty-eight competent persons marked the paper. The distribution of the scores was as follows: 45, 59, 67, 67.5, 70, 70, 72.5, 75, 75, 75, 75, 75, 75, 77, 80, 80, 80, 80, 80, 82, 82, 85, 85, 87.5, 88, 90, 100, 100. The difference between the highest and lowest marks was 55. The paper was perfect in the opinion of two teachers, while four others thought it was below the standard required for passing.[2]

The classic experiments of Starch and Elliott[3] at the University of Wisconsin demonstrated in a most convincing manner the variability of marks given by different teachers to the same papers in typical school subjects. Plates were made of two final examination papers in high school freshman English, one in geometry and one in American history so that the penmanship, legibility, errors, corrections made by the pupils were reproduced exactly as in the original papers. Then these papers and the questions asked were sent to representative teachers in English, mathematics and history respectively, to be graded. A tabular digest of the results follows:

Final Examination Paper	*Number of Teachers*	*Distribution of marks*
1. English	142	64 to 98
2. English	142	50 to 98
3. Geometry	114	24 to 92
4. American History	70	43 to 90

[1] Hopkins, L. T.: The Marking System of the College Entrance Examination Board, Harvard Monographs in Education, Series 1, No. 2, October, 1921, p. 8.

[2] Kelly, F. J.: Teachers' Marks, Their Variability and Standardization, Teachers College, Columbia University Contributions to Education, No. 66, 1914, p. 51.

[3] Starch, D. and Elliott, E. C.: "Reliability of Grading Work in English," The School Review, 20: 442-57, September, 1912.

Gray[4] procured a set of eleven examination papers in senior English and a set of twenty examination papers in solid geometry from a high school in southern Indiana. He attached a copy of the questions used to each set and sent them to five highly trained experts in secondary school work in addition to the class teacher and requested them to grade the papers on a separate sheet numbered for this purpose. It was understood that 70 was to be the passing mark in each case. The averages of the grades assigned by the six teachers are shown in the following table:

Set of Papers	*Average Marks of Teachers*						*Difference between Average Marks of High and Low Marker*
	A	B	C	D	E	F	
Mathematics	78.7	74.0	61.4	65.5	75.5	58.0	20.7
English	90.3	83.7	78.5	54.0	70.0	59.5	29.7

Teachers on re-grading their own papers without knowledge of their former marks are inconsistent to an appreciable extent. In an experiment carried out by Starch[5] seven teachers re-marked their papers and it was found upon comparing the first grade with the second for each paper that the mean variation of these grades was 2.2 points.

The following table adapted from Starch[5] presents the gist of his findings:

Subject	*Number of papers*	*Interval between First and Second Grading*	*Average Difference of the First and Second Marks*
1. Advanced Psychology	10	2 years	4
2. Elementary Psychology	10	2 weeks	3
3. Elementary Psychology	10	4 years	4.6
4. Mathematics	10	9 months	7.8

———, "Reliability of Grading Work in Mathematics," The School Review, 21: 253-59, April, 1913.

———, "Reliability of Grading Work in History," The School Review, 21, 676-81, December, 1913.

[4] Gray, C. T.: Variations in the Grades of High School Pupils.

[5] Starch, D.: Educational Psychology, pp. 437-8.

Subject	*Number of papers*	*Interval between First and Second Grading*	*Average Difference of the First and Second Marks*
5. Mathematics.....	10	9 months	2.1
6. English.....	8	6 months	2.8
7. German.....	10	6 months	6.5

Inglis[6] sent a set of ten questions in plane geometry to about 300 head teachers of mathematics in high schools in the Middle Atlantic States and requested them to express their opinion regarding the relative weights that should be apportioned to the problems on the assumption that the total number of points should equal 100. Twenty of the 122 replies received agreed in giving equal values of 10 to all of the questions, and the other 102 judgments indicated a wide diversity of arbitrary ratings. Inglis then examined a high school class in mathematics of 40 pupils in order to find out the relative difficulty on the basis of their ability to answer the problems correctly. Finally, he compared the relative values as determined by the judgments of teachers and the difficulties of pupils and the results differed markedly.

Investigators give various causes for this unreliability. An extract from a recent article pertaining to the subjective character of marks is worth repeating in this connection.

"I am firmly convinced that the grading of pupils' work is often influenced by the state of health of the marker, both the physical and mental state. A spell of indigestion is apt to lower all grades, and the prospects of an increase in the salary may boost them. I have found in my own case that the same mistake in the first half dozen papers of a class received a more severe cut than the twenty-fifth. The mind becomes accustomed to the error, and we think more charitably of it."[7]

Other factors contributing to this untrustworthiness of instructors' gradings have been found to be native capacity of the pupils for particular subjects, quantity and quality of performance, supplementary information, organization and relevancy of ideas,

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[6] Inglis, A. J.: "Variability of Judgments in Equating Values in Grading," Educational Administration and Supervision, 2: 25-30, January, 1916.

[7] Armstrong, J. E.: "Variation in Grading High School Pupils," Chicago Schools Journal, 4: 346–8, May, 1922.

temporary memory of facts, a good guess as to the probable questions to be asked, a few nights' grinding, the state of health of the pupils, temperament, earnestness, initiative, perseverance, ideals and neatness.

Recognizing the variability of teachers' marks and the causes of this variability, different plans have been devised for securing greater uniformity. One of the most common is the use of the normal probability curve as a basis. It is argued that since practically all the human traits are found to be distributed roughly according to the normal probability curve that, therefore, teachers' marks should approximate that curve. On a five point basis, in the long run the number of students who should receive each of the five grades should theoretically be as follows:

		A	B	C	D	E
Cattell	(1905)	10%	20%	40%	20%	10%
Meyer	(1908)	3	22	50	22	3
Dearborn	(1910)	2	23	50	23	2
Foster	(1911)	3	22	50	22	3
Slosson	(1911)	3	22	50	22	3
Smith	(1911)	10	15	50	15	10
Ruediger	(1912)	4	24	44	24	4
Gray	(1913)	7	22	42	22	7
Cajori	(1914)	7	24	38	24	7
Starch	(1917)	7	24	38	24	7[8]

An interesting modification of this method is seen in the practice of some principals of arbitrarily changing the mark of a teacher who departed too much from the standard deviation. It has been suggested that the marks be tabulated at regular intervals and their distribution compared with the surface of frequency of the probability integral. Wide deviations on the part of any teacher should be sufficient reason for investigation by the head of the department, the principal or other administrative authorities. Grades if decidedly irregular in distribution may then be equitably adjusted, by making an allowance for the relative severity or leniency of the teacher as the case may be, until a reasonable conformity with the Laplace-Gaussian curve is obtained.

But such plans merely treat the symptoms of unreliability in

[8] Hopkins, L. T.: The Marking System of the College Entrance Examination Board, Harvard Monographs in Education, Series 1, No. 2, October, 1921, p. 12.

teachers' marks. They take for granted that the forms of examinations are entirely right as they are and that variations are due to those marking them. They do not recognize that one of the chief causes for variability may be imperfections inherent in the nature of the examinations themselves. It is the firm conviction of the writer that such is the case. If this be true the so-called scientific marking system while sound in theory cannot be regarded as a satisfactory solution of the problem.

Aims of the Study

1. To investigate the reliability of the conventional written examination as a measure of accomplishment for the purpose of devising a more scientific technique of conducting tests, readily adjustable to the aims, content, methods of instruction, and teaching emphasis of the individual teacher.

2. To gather by means of a questionnaire all the data possible relating to the general situation with respect to the construction, administration and grading of written examinations in representative high schools in all parts of the United States, from the point of view of the realization of fundamental educational objectives, and the dependability of the results, with particular attention to the objectivity of the marks and the influence of elements other than those the examinations presumably are intended to measure.

3. To try out conventional tests in General Science, largely taken from sample sets secured from other teachers and new achievement tests, both covering practically the same content, with the author's classes.

4. To analyze the relative advantages and disadvantages of the conventional and new types of tests on the basis of past studies in this field, the facts regarding prevailing practices brought out by the questionnaire, and experimentation with two groups of pupils extending over two terms.

Outline of Plan of Study

1. Investigation of Prevailing Practices in Representative High Schools.

Questionnaires were sent to accredited high schools in all sections of the United States in order to reveal prevailing practices

with respect to the written examination as a measure of achievement, with particular reference to General Science. As an important supplementary feature, teachers were asked to enclose sample sets of questions used and typical examination papers representing superior, average and poor students. It was hoped that this would provide concrete embodiment of the practices referred to in the questionnaire.

2. Experimentation with General Science Classes.

An experiment was conducted for a period of two semesters with classes in General Science in order to compare the conventional and new types of tests as scientific measures of accomplishment. Three pairs of these tests were given each term to the same pupils, each pair as a whole covering equivalent subject matter. An arbitrary marking system was used. The reliability of the scores in each case received particular attention. The character of the distribution of these scores, with reference to the ideal bell-shaped normal probability curve, as a partial indication of objectivity could not be ascertained directly in accordance with approved statistical practice owing to the small number of pupils included, therefore an indirect plan was adopted.

3. Interpretation of Results.

The relative advantages and disadvantages of each type of test were assembled and critically analyzed from the standpoint of fundamental educational objectives.

Limitations of Study

1. Relative Values of Written Examinations Problematical.—We do not know how important the written examination should be in measuring accomplishment in any particular subject. There is a tendency to limit the number of examinations in the high school. (The high schools in Philadelphia and in many other cities no longer have final examinations.)

2. Arbitrary Marking System Used.—Marks and marking systems cannot be entirely dissociated. This investigation is not primarily concerned with marking systems and an arbitrary plan was adopted that seemed to be scientifically tenable.

3. Subjective Elements in Marking of the Conventional Examinations.—The writer constructed and graded both the

conventional and the new tests given to the General Science classes, therefore, some of the disadvantages of the ordinary examination did not apply, or at least not to the same degree. A fairer contrast between the two types of tests would have resulted if different teachers had framed the questions for the usual form of test, after a consultation regarding the topics covered, and then a group of teachers had marked them independently of each other. The inclusion of subjective and other irrelevant elements in the marks assigned can be determined only by examiners not conscious of the objectives of the experiment. (Therefore a valid analysis duplicating that made of sample papers submitted along with the questionnaires was impracticable.)

4. Indirect Plan of Ascertaining Distribution of Scores.—It is presupposed that the distribution of marks on a large enough scale in any subject should approximate the normal probability curve, but the limited number of pupils in the experiment prevented a direct comparison of the distribution of the two kinds of tests on an accepted scientific basis. Because of this it seemed desirable to compare each type of test with some third test whose distribution we knew and in which the scores might reasonably be expected to bear a significant association with scores in achievement tests. The inference was made tentatively that the one having a higher correlation with the general intelligence tests, the best available indices of educability, more closely approaches the absolute theoretical distribution of abilities in General Science.

5. Irrelevant Elements in Marks.—It is assumed that varying abilities in spelling, English, penmanship, speed in writing and drawing should not enter into the measurement of accomplishment in science.

6. Performance Tests not included.—Performance tests corresponding to those utilized in trade tests would have been excellent measuring devices of certain skills in applied science. But large classes in a crowded high school and the lack of facilities for individual laboratory work on the part of the students prevented their inclusion.

Summary

1. The written examination is an important measure of achievement in subject matter.

2. Marks given for tests largely influence the career of the pupils.

3. Studies by Hopkins and others indicate a large percentage of high school failures.

4. Experiments by Kelley, Starch and Elliott, Gray and other investigators strongly point to the fact that teachers' marks are subjective and unreliable.

5. A realization of the unreliability of marks led to the evolution of the so-called scientific marking system intended to make them conform to the normal probability curve. But such a plan does not get at the underlying causes of the condition and cannot be regarded as a satisfactory solution of the problem.

CHAPTER II

AN INVESTIGATION OF PREVAILING PRACTICES WITH RESPECT TO WRITTEN EXAMINATIONS IN REPRESENTATIVE HIGH SCHOOLS

The question-blank method was used for the purpose of obtaining a cross section of the prevailing practices relative to the organization, administration and systems of grading written examinations in representative high schools in all parts of the United States. Under the direction of Professor A. J. Jones, with the assistance of members of the seminar in secondary education at the University of Pennsylvania, preliminary forms were devised and submitted in typewritten form to twelve high school teachers in Philadelphia and nearby cities with a request that they fill out the questionnaire and offer criticisms or suggestions for its improvement. On the basis of the clearness and definiteness of the original questions as indicated by the relevancy of the answers given, the final form which follows was constructed and printed.

2114 North Natrona Street,
Philadelphia, Pa.
——, 1922.

Dear Sir:

This inquiry is being conducted under the guidance of Dr. A. J. Jones, Professor of Secondary Education in the Graduate School of the University of Pennsylvania. Definite information is being sought relating to the nature of written examinations and methods of marking them in representative high schools in all sections of the United States, with particular reference to General or First Year Science courses.

Past investigations in this field have stressed for the most part the unreliability of written examinations as an adequate measure of achievement, and have slighted the essential worthwhileness of periodic tests as a necessary part of the educative process.

The information obtained with your cooperation will be used

to study constructively desirable practices in different high schools as a basis for the development of practical scientific principles of procedure in the formulation and grading of written examinations. The name of the schools will not be mentioned, but referred to by numbers.

Kindly request one of your teachers in General Science or First Year Science, after consultation with you, to fill out the enclosed inquiry. I hope the questions appeal to you as being relevant to the study and that they are clear so that they can be answered readily. If General Science is not taught in your high school, the inquiry refers to any first year science course. If it is impractical to answer all of the questions, please fill out as many of them as you can. Whatever help you can give me will be appreciated.

Yours sincerely,
JOSEPH BARDY.

QUESTIONNAIRE ON WRITTEN EXAMINATIONS AND MARKING SYSTEMS

A. The School. (Please fill out the following facts.)
   1. Name of the High School.
   2. Grades in which General Science is given (7, 8, 9, 10, 11, 12).
   3. City. County. State.
   4. Enrollment in High School.
   5. Number of boys in General Science classes.
   6. Number of girls in General Science classes.
   7. Total number of students in General Science classes.
   8. Are boys and girls taught in the same or in separate classes in General Science? (Check proper word.)

B. The Written Examination. (Please answer the questions by a check mark or by a number as is appropriate, unless otherwise directed.)
   1. How often are written examinations given?
      Weekly
      Monthly
      Twice a term

At irregular intervals (At any other intervals)

2. Is a final examination given at the end of the term?
   Yes. No.
3. What is the usual number of questions?
4. Are these questions usually subdivided? Yes. No.
5. Do you allow choice of questions? Yes. No.
6. What is the usual length of time allowed for the examinations? minutes.
7. How are the students permitted to answer?
   In ink
   In pencil
   In either ink or pencil
8. About what percentage of the students find time to finish all the questions in the examinations? %.
9. How are the questions given to the students?
   Dictated.
   Written on the board.
   Mimeographed (or duplicated).

C. Marking the papers.

1. Do the following factors lower the mark?
   Legibility.
   Clarity of the English used.
   Spelling.
   Grammar.
   Paragraphing.
   Numbering of questions.
   (Add any other factors).
2. Do all questions receive an equivalent valuation? (i.e., if five questions, each receives 20) Yes. No.
3. If not, what is the basis?
   Probable number of words and length of time to clearly answer the questions.
   Complexity of factors to be taken into consideration.
   Relative importance of the different questions asked.
   Relative difficulty of questions in opinions of teachers.
   Relative difficulty of questions as indicated by answers of pupils.
   (Add any other method).

4. Is the length of the examination based upon any of the following principles?
   None can finish on time.
   The superior students can finish on time.
   The average students can finish on time.
   All can finish on time.
5. Are there any adjustments made for papers in which all the questions were not answered but all attempted were answered exceptionally well? Yes. No.
6. Which of the following factors influence the mark?
   The total number of questions.
   The number of questions answered.
7. Do you have one standard for all students in marking?
   Yes. No.
8. Do you have different standards for superior, average and poor students? Yes. No.
9. What percent. of the final standing do the written examinations during the term count? %.
10. What percent. of the final standing does the final examination count? %.
11. What is your system of marking?
12. What is the passing mark?
13. What numerical value has the passing mark, if any?
14. What was the percent. of failures in your subject during the following terms?
    February, 1920-June, 1920. %
    September, 1920-February, 1921. %
    February, 1921-June, 1921. %
    September, 1921-February, 1922. %

D. Supplementary Examinations.

1. Are performance tests given in laboratory work?
   Yes. No.
   Are they considered in grading and promotion?
   Yes. No.
2. Are General Intelligence Tests given?
   Yes. No.
   Are they considered in grading and promotion?
   Yes. No.

3. Are standard tests in High School Science given?
   Yes. No.
   Are they considered in grading and promotion?
   Yes. No.

E. Typical Examination Papers.
   1. Please enclose a set of questions used in a final examination or its equivalent during the term in General Science.
   2. If possible, also enclose examination papers representing superior, average and poor students.

F. Remarks.

The selection of schools was based on a list of accredited secondary schools compiled by the United States Bureau of Education.[1] This was checked for each state by noting the population[2] of the cities in which these schools were located. An effort was made to secure a fair sampling of high schools in the largest available cities in all states.

Two copies of the questionnaire were mailed to high schools in cities having a population of 500,000 and over, and one copy to high schools in smaller cities. A self-addressed and stamped envelope was enclosed for the reply. The accompanying letter of explanation was addressed to the principal instead of to a teacher in order to increase the number of replies. By enlisting his cooperation—he was not asked to fill out the inquiry himself—it was felt that he would not be so likely to drop it into his waste-paper basket, and would select a teacher sufficiently interested in educational research to answer it. At first they were not distributed to schools in cities having less than 10,000 inhabitants, but as the returns came in it became evident that this tentative limit would have to be lowered in order to get returns from thinly settled states like Idaho, Nevada, New Mexico and South Dakota. At intervals of about four or five weeks, additional copies of the inquiry and follow-up letter were directed to schools not yet heard from, stressing the importance of the investigation, its constructive

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[1] Capen, S. P.: Accredited Secondary Schools in the United States, U. S. Bureau of Education, Bulletin 1915, No. 7.

[2] Fourteenth Census of the United States, Vol. 1, Population, Number and Distribution of Inhabitants, pp. 178-319.

character and the desirability of having typical school systems in every part of the country represented. After four such appeals in a few instances, returns were obtained from all 48 states and the District of Columbia. In all about 700 questionnaires were distributed to 500 different schools, and 241 replies were received. Twenty-one of them were filled out with reference to courses other than General Science.[3] An abstract of the returns follows.

Part I

Abstract of Answers to Questionnaire

Table 1

General Data Relating to Schools in Study

The names of the 236 high schools cooperating in the investigation are given in the Appendix, Section 1.

	Number	*Percent of schools giving information*
A. Size of city in which High School is located.		
500,000 and over	13	7
100,000 to 500,000	41	20
50,000 to 100,000	33	17
25,000 to 50,000	53	26
10,000 to 25,000	52	26
Below 10,000	7	4
Total	199	
B. Enrollment in High School		
3,000 and over	14	6
2,000 to 3,000	32	15
1,000 to 2,000	77	35
500 to 1,000	73	33
100 to 500	22	10
Below 100	3	1

C. Grades in which General Science is given.	*Number*	*Percent of schools giving information*
7–8	5	3
7–9	1	less than 1
7–10	1	less than 1

[3] See Appendix, Section 1.

		Number	*Percent of schools giving information*
	8	17	9
	8–9	11	6
	9	143	72
	9–10	10	5
	9–12	1	less than 1
	10	6	3
	10–12	1	less than 1
	11	1	less than 1
D.	Number of pupils in General Science classes.		
	Boys	22,960	44
	Girls	28,695	56
	Total	51,655	
E.	Boys and Girls taught in same or separate classes		
	In same classes	183	89
	In separate classes	15	8
	In same and separate classes	7	3

TABLE 2

THE WRITTEN EXAMINATION

		Number	*Percent of teachers answering question*
A.	Frequency of written examinations. (More than one method used in many cases.)		
	Weekly	14	
	Every two weeks	8	
	Monthly	73	
	Every two months	3	
	Two times a term	31	
	Three times a term	22	
	Four times a term	10	
	Six times a term	4	
	At irregular intervals	119	
B.	Final Examination at end of term.		
	Final examination given	167	71
	Final examination not given	67	29
C.	Usual number of questions.		
	Less than 5	2	1
	5	29	14
	5–10	54	27

	Number	*Percent of teachers answering question*
10	97	46
10–15	17	8
15–20	7	3
More than 20	3	1

	Number	*Percent of teachers answering question*
D. Subdivision of Questions.		
Questions subdivided	176	78
Questions not subdivided	50	22
E. Choice of questions.		
Choice of questions allowed	148	75
Choice of questions not allowed	49	25
F. Usual time limits in minutes. (More than one method used in some cases.)		
Less than 40	12	
40–45	98	
45–60	30	
60–90	73	
90–120	38	
More than 120	35	
G. Use of ink or pencil.		
Ink permitted	78	33
Pencil permitted	5	2
Ink or pencil permitted	154	65
H. Percentage of pupils finishing the the examination.		
100	76	34
90–100	112	50
80–90	17	8
70–80	12	6
Below 70	4	2
I. Usual Method of administration. (More than one method used in many cases.)		
Dictated	37	
Written on board	170	
Mimeographed, duplicated, or printed	129	

TABLE 3

MARKING THE PAPERS

		Number	*Percent of teachers answering question*
A.	Factors included in mark. (More than one factor included in many cases.)		
	Legibility	125	
	Clarity of English used	138	
	Spelling	119	
	Grammar	91	
	Paragraphing	55	
	Numbering of questions	51	
	Specific instructions not followed	1	
	Neatness	4	
B.	Influence of legibility, English, spelling, etc. on mark.		
	Lowers mark in a general way	160	70
	Deductions ranging from 5 to 10%	7	3
	Does not lower mark	43	19
	Issue dodged	20	8
C.	Relative valuation of different questions.		
	Equivalent	112	49
	Not equivalent	118	51
D.	Basis of valuation of different questions. (More than one basis included in many cases.)		
	Probable number of words in answer	29	
	Compexity of factors involved	64	
	Relative importance	125	
	Relative difficulty in opinion of teacher	75	
	Relative difficulty in opinion of pupils	32	
	Thoroughness of class discussion	1	
	No set policy	1	
	God knows	1	
E.	Factors determining length of examination. (More than one factor included in many cases.)		
	None can finish on time	2	1

		Number	*Percent of teachers answering question*
	Superior students can finish on time	8	3
	The average student can finish on time	120	46
	All can finish on time	110	50
F.	Adjustments in marks.		
	Adjustments for unfinished papers	155	71
	No adjustments	63	29
G.	The number of questions as a factor in mark.		
	The total number of questions used as basis	91	45
	The number of questions attempted used as basis	72	36
	Both the total number and the total number of questions attempted used as basis	38	19
H.	Standards.		
	One standard for all students	166	76
	Different standards for superior, average and poor students	53	24
I.	Percentile value of Written Examinations during term, in final standing.		
	10 or less	2	1
	15	4	3
	20	15	9
	25	33	20
	30	5	3
	33⅓	78	46
	40	5	3
	50 or more	27	15
J.	Percentile value of final examination in final standing.		
	10 or less	4	3
	15	5	4
	20	21	14
	25	27	18
	30	2	1
	33⅓	74	48
	40	3	2
	50 or more	14	10

	Number	*Percent of teachers answering question*
K. Systems of Marking.		
Percentile system	60	35
10 number system	2	1
6 letter system	14	8
6 number system	1	1
5 letter system	50	29
5 number system	10	6
4 letter system	32	18
4 number system	2	1
Credit for quality	2	1
L. Numerical value of passing mark.		
50	1	less than 1
60	19	9
65	11	5
70	113	50
75	66	29
80	5	2
No numerical value	10	5
M. Average percent. of failures between February, 1920 and February, 1922.		
30–39	4	3
20–29	19	11
10–19	73	43
0–10	72	43

TABLE 4

SUPPLEMENTARY EXAMINATION

	Given	*Not Given*	*Counted in grading and promotion*	*Not counted in grading and promotion*
Performance Tests[4]	78	172	67	7
General intelligence tests	75	117	38	26
Standardized tests	27	144	16	3

TABLE 5

TYPICAL EXAMINATION PAPERS

Sample sets of examinations	*Number of sets*	*Number of papers*	*Number of schools*
General Science	92		57
Physical Geography	6		5

[4] In many cases probably interpreted to mean laboratory tests.

	Number of sets	*Number of papers*	*Number of schools*
Biology	22		12
Physiology	2		2
Examination papers representing superior, average and poor students.			
General Science	19	58	17
	1 (class set)	30	1

Conclusions

If the practices of the 241 high school teachers who cooperated in the investigation represent a fair sampling of the general situation relative to the construction, administration and marking of written examinations, then the following conclusions seem to be warranted:

1. General Science is taught usually in the ninth school year.

2. Written examinations are held generally at irregular intervals depending upon the completion of major topics of the subject. Monthly examinations and those held twice or three times a term rank next in frequency in the order named.

3. Final examinations are given in most high schools.

4. About 86% of the teachers give 10 questions or less in an examination, 73% subdivide the questions, and 61% allow choice of questions.

5. The time allowance for the average written test is 40 to 45 minutes, or a standard high school period. For final examinations this is often 1, 2 or 3 hours.

6. Students are permitted to use either ink or pencil in most tests.

7. A majority of the pupils find time to finish all the questions in examinations.

8. As a rule the questions are written on the board. Sometimes, especially in final examinations, they are mimeographed (duplicated) or printed.

9. In a general way factors like penmanship, spelling, English and the like are included in the mark by 72% of the teachers. In a few cases a definite system of deductions is used.

10. One-half of the teachers give questions equivalent valuations and one-half do not. In the latter case the valuations depend either on the relative difficulty or relative complexity of the questions in the opinion of the teachers concerned.

11. Teachers aim to make the length of the examination either such as will enable the average student or all to finish on time.

12. About 71% of the teachers do not mark papers on a strictly mathematical basis but make adjustments for a number of reasons. 55% grade on the basis of the total number of questions, and 45% on the number attempted; 75% have one standard for all students and 25% have different standards for superior, average and poor students.

13. Generally the final grade is a blanket mark made up either of 1/3 for daily recitations, 1/3 for term tests, and 1/3 for final examination; or 1/2 for daily recitations, 1/4 for term tests and 1/4 for final examination.

14. About 65% of the teachers use the letter or number system in grading on a 4, 5, 6 or 10 point scale and 35% still use the percentile system. The numerical equivalent of the passing mark is 70 to 75 in most instances.

15. The average percent. of failures in General Science is about 12.

16. Supplementary examinations such as group intelligence tests, standard tests and performance tests are not included in the regular examination system of high schools.

Part II

Sample Sets of Examination Questions and of Examination Papers Representing Superior, Average and Poor Students

selections with annotations

A. Examination Questions in General Science

1. Long Sets of Conventional Examination Questions

Example 1. (*Time allotment—90 minutes.*)

1. What bodies make up the solar system? What is the cause of the sun's light?

Describe and locate a constellation which is visible all the year. Explain its apparent motion from hour to hour. Tell how to find the north point on the horizon. In what direction do shadows lie just before noon? Why? How much of the moon is illuminated at one time? What is the apparent form of the moon at first quarter? Explain. Make a lettered diagram to show the positions of bodies causing a solar eclipse.

2. (a) Find the density of a piece of marble which weighs 97.5 grams and which immersed in water causes it to rise from the 175 to the 210 cu. cm. line.
   (b) Find the weight of a block of stone 2 m. long; 8 dm. wide and 15 cm. thick if its density is 2.8 g. per cu. cm.
   (c) Find the difference in pressure on the top and the bottom of a cube 5 cm. on an edge when the upper surface is 10 cm. under water. To what is this difference equal?
3. Define matter, force, weight.

   What is a machine? Name three simple machines. Describe one of these and name two advantages derived from its use.

   What effects may the lowering of temparature have upon a solid? a liquid? a gas? Describe the process of distillation. How many calories are needed to raise the temperature of a liter of water from 0 degrees C. to 25 degrees C?

   If the area of the small piston of a hydraulic press is 4 sq. in., and the area of the large piston is 200 sq. in., what force will 10 lbs. pressure on the small piston exert on the large piston?
4. Why is the density of air greatest near the surface of the earth? Tell how to construct a simple barometer. What is the reading of a barometer at sea level under ordinary conditions? What changes in the atmosphere may cause a lower reading? If the reading of the barometer at the foot of a mountain is 28 in. and at the top 21 in., what is the height of the mountain?

   A quantity of gas occupies 2100 cu. cm. space under ordinary conditions. What will be its volume under (a)

seven times as great pressure? .(b) one third as much pressure?

What weather conditions exist in the Belt of Calms? Why is this belt so named? Why does its position change with the seasons? Explain the cooling of air after a shower. Define weather.

5. Use correctly in a single sentence concerning light, the following words: (a) transparent and transmit; (b) opaque and reflect.

If a rainbow is visible at 8 a.m., in what part of the sky must it be? Explain.

Make a diagram of an electric bell showing the place of the push button and its connection with battery. Explain the operation of the bell.

What is the cause of a flash of lightning? How far away is this flash if we can count thirty between the time of seeing the flash and hearing the thunder?

Example 2. (*Time allotment—90-150 minutes*)

I. Explain or Define:

1. Molecular theory
2. Atomic theory
3. Evaporation
4. Condensation
5. Dew point
6. Humidity
7. Saturation
8. Chemical decomposition
9. Simple substance
10. Compound substance

II. Laboratory Work.

Prove: 1. That air has weight.
2. That air expands when heated.
3. That air can be compressed.
4. That a liquid does not fill all the spaces that it appears to fill.
5. That the products of a burning candle are CO_2 and H_2O.
6. That water is made up of H_2O.
7. That water evaporates from plants.
8. That the central part of a flame is composed of unburned gas.
9. That soil heats more quickly than water.

10. That water evaporates when the temperature is below freezing point.

III. Water.
1. Give the boiling and freezing points of water on the Centigrade and Fahrenheit scales.
2. Of what is water composed?
3. Give three ways in which water may be purified.
4. Discuss the water supply of your city relative to source, purity, amount used per day, and cost per year.
5. What two diseases are spread by water?

IV. Air.
1. Give the composition of the air.
2. Give the barometer reading at sea level.
3. Give air pressure per sq. in. at sea level.
4. How do plants purify the air for animals?
5. What are the uses of the three most important gases of the air?

V. Give symbols for:
Carbon, gold, hydrogen, iodine, lead, oxygen, nitrogen, silver, sulphur, zinc.

VI. Evaporation:
1. What effect does evaporation have on the temperature?
2. Why does ether lower the temperature more than water when it evaporates?
3. Explain how an ice machine works.
4. Explain why perspiring cools the body.
5. Will clothes dry at a freezing temperature?

Example 3. (*Time allotment—180 minutes*)

1. Name four kinds of energy. Give a device which transforms each kind mentioned into some other form. Draw a diagram of a steam engine; label the parts and tell from where its energy is obtained.
2. Draw a diagram of an electric bell connected with a dry cell. Indicate by arrows the direction of the flow of electricity and give each step in the ringing process. Tell what kind of magnetism is induced in the coils. How could you make

a permanent magnet? Give the laws of the magnet. Give three uses of temporary magnets and three uses of permanent magnets.

3. Four men pulling 150 lbs. each having a mechanical advantage of six (6) can raise only 3492 lbs. What is the efficiency? the loss? Where does the loss go and why?
4. (a) Sketch a series circuit; a parallel circuit. In which is the current the same in all the members? In which is the voltage the same?

   (b) Sketch an electro-plating circuit and give general names for the various materials required.
5. Name the planets in order of size. Give comparative effects of mass on weight in the case of Mercury and the sun. Give four reasons why it is thought that Mars might be inhabited.
6. Write a 250 word paragraph on the sun, telling its distance from the earth, the speed of light and therefore the time which it would take sunlight to reach us, storms on the sun, and tell how we know that the sun has the same elements as the earth.
7. Describe the plant covering of the earth, starting with the mountain and continuing to the ocean bed, indicating the kind of covering on each level. Describe the variation in covering on each level. Describe also the variation in covering according to climate and rainfall.
8. What is meant by the following:—Plant association, osmosis, capillary action; protein; synthesis; grafting; pollinization; step-up; electroplate; erosion; inoculation.
9. Give in as much detail as you require the complete course of energy from the sun through all the necessary mediums to the steam engine.
10. Draw a diagram of the blood circulatory system in the human body. Indicate by arrows the direction of the flow. Describe the structure of the heart, accounting for the different thicknesses of chamber walls and valves.
11. (a) Give ten rules of personal hygiene which would help you to fight bacterial disease.

(b) What is the outcome of the struggle for existence? When conditions are made too favorable for any species what is the result?

12. What two kinds of reproduction are there? Describe that for which seeds are necessary.
13. How is the nitrogen of the air obtained by plants and of what use is it?
14. What influence has the moon upon the earth? Can the moon have an atmosphere and why? What is the source of the moon's light?
15. Sketch the alimentary canal, naming the principal parts in their proper positions, in diagrammatic form.

Comments

1. The physical and mental fatigue caused by taking an examination lasting for one, two or three hours is probably too great for pupils of the ninth school year. The time should not exceed 45 minutes. Thirty minutes would perhaps be still better.

2. There seemed to be an effort to make the examinations comprehensive and at the same time to make them appear of reasonable length. But the 5 questions in the first specimen may be broken up into 49 questions; the 6 questions in the second specimen, into 36 questions; and the 15 questions in the third specimen, into 68 questions. It is impossible to determine the amount of discussion required to answer them. This would vary considerably with different topics and the amount of detail involved. However, it is evident that a great deal of writing was necessitated. Consequently, speed in writing and physical fatigue were bound to be factors entering into the results.

3. Mental processes go on faster than those of the mechanics of writing. Sometimes parts of complex questions are overlooked by students in their hurry to record their thoughts and to finish on time. In addition, there is the inhibiting influence of putting the discussions in good English. Therefore, it follows that the slower the writer and the weaker his control of the mother tongue, the less likely he will be to do himself full justice in the specific subject-matter of the examination.

2. Long Examination Questions Containing partly related or unrelated subdivisions

Miscellaneous Examples from different Sets of Examination Questions

1. Name some foods that you eat that are rich in carbo-hydrates; some that contain fats; and some that are rich in proteids. Which of these are fuel foods? Use of fuel foods to the body? Which of these are fuel foods to the body? Which of these are building foods? Name foods containing the fat-soluble vitamine and tell what use this vitamine is to you. What is a calorie? You should eat food that will furnish you with how many calories daily?
2. Define: ptomaines, inoculation, lodestone, inertia, anther, pupa, anopheles, spectrum, fuse, convection.
3. Tell how to prepare and describe the properties of the following gases:—(a) oxygen, (b) hydrogen, (c) carbon dioxide.
4. Draw a figure showing earth, sun's rays, moon's rays, part of the earth in sunlight; part of earth in moonlight; mark the place where it is sunrise, noon, sunset, midnight, moonrise, and moonset, when the moon is full.
5. Write clearly upon the topic of sound including the following:—
   A. a. Definition of sound.
      b. Cause of sound.
      c. Sound waves.
      d. Relation between closed and open organ pipes and wave length.
      e. Velocity of sound and method of determining.
      f. Sympathetic vibration.
      g. Variation of velocity of sound and cause.
   B. The wave length of a tone is 4.4 ft. The length of the organ pipe is 1.1 feet. Is the pipe open or closed?
6. A. a. Name the simple machines.
      b. Draw diagrams showing the classes of levers and state the law of the lever.
      c. What is the law of the pulley?
      d. Name at least 5 examples of levers and state the class to which each belongs.

B. A force of 100 lbs. is placed 10 in. from the fulcrum of a first class lever. For equilibrium what force must be placed 50 in. from the fulcrum?

7. a. What is the advantage in using a single fixed pulley?
b. Define the foot-pound.
c. What is the speed of sound?
d. Why can we draw water to only a height of 32 ft. in the common suction pump?
e. What does a high reading of a barometer indicate?
f. Name the primary colors.
g. What kind of lens is a remedy for farsightedness?
h. Define refraction.
i. Define a volt.
j. What commonly are the electrodes used in setting up a simple voltaic cell?

8. Define or explain the following expressions:
Vernal equinox, magnet pole, neutralization, kindling temperature, hygrometer, diffusion of gases, transpiration, siphon, aneroid, Pasteur.

9. Define:

atom	centrifugal force
conservation of matter	piracy
compound	contour line
chemical affinity	barometer
gravitation	strata

10. (Be brief in your answers to these questions.)
a. What is meant by 18 carat gold?
b. What is the effect when two north poles of two magnets are brought together?
c. Why does ice float? What advantage is this?
d. Why is a mordant sometimes used in connection with dyeing of cloth?
e. What is the effect of heat on starch?
f. How can ink be removed from cloth?
g. Why is bluing used in the laundry?
h. What gas does baking powder liberate in baking?
i. What effect does an acid have on litmus?
j. Why does metal feel colder than wood in the same room?

COMMENTS

1. The criticism of long examinations relative to the amount of writing entailed, the resulting physical and mental fatigue, and the other objections noted, apply equally well to the selected questions from various sets grouped here.

2. Numbers 1, 3 and 4 really consist of 10, 3 and 10 partly related questions, respectively. Numbers 5 and 6 similarly are made up of 8 and 5 partly related and lettered subdivisions, respectively. Numbers 2 and 8 each have 10 unrelated questions grouped together. Numbers 7, 9 and 10 each have 10 unrelated, lettered subdivisions.

3. The lettering of the sub-parts in some of the cases given lessens the chances of omissions due to oversight, but this does not justify the groupings of miscellaneous, separate topics under one question. Complex questions with numerous subdivisions, even if closely related in order to force the appearance of conformance to a traditional 5 or 10 questions per examination, is illogical and undesirable. It is far better to make each question bear on one topic only, without regard to the total number in an examination.

3. Indefinite, Imperfectly Worded Examination Questions
Miscellaneous Examples from different Sets of Examination Questions

1. Write a paragraph about atmospheric pressure.
2. Write a paragraph on "How Rock Becomes Soil."
3. Write a paragraph of 10 lines about the bones of the body.
4. Write a paragraph of 75 words on the migration of birds, and bird life left in this country from November to March.
5. Tell in 8 or 10 lines the principal facts about the Chicago water system.
6. Write all you can about bacteria and disease germs.
7. Write all you can about the climatic influences of large bodies of water.
8. Write a question regarding any particular thing you have learned in the course so far and answer your question yourself.
9. Do you know any reasons for cultivating the soil other than killing weeds?

Comments

In numbers 1, 2, 3, 4, and 5, according to a strict logical interpretation of the wording, any paragraph on the particular topics concerned, provided it conforms to the specifications as to form and length, even though the most important elements for discussion are not selected, is theoretically entitled to full credit.

In numbers 6 and 7 it is not clear how much the pupil is expected to know about bacteria and disease germs, and climatic influences of large bodies of water, respectively. If he "can" write only one simple statement he seems to fulfill all the technical requirements of a perfect answer.

In number 8 too much leeway is given to the pupil. He may select an easy question which can be answered correctly in a few words, while perhaps another more conscientious pupil may select a difficult one necessitating an elaborate discussion.

In number 9 some pupils may regard either "yes" or "no" as correct answers to the question.

Conclusions

1. Some conventional examinations are of unreasonable length and demand a considerable amount of writing in order to answer all the questions adequately.

2. It is not uncommon for questions to consist of partly or entirely unrelated subdivisions. A separating out of dissociated topics under a logical plan of enumeration is more desirable.

3. Questions are sometimes imperfect in construction and thereby conducive to an increase in variability of performance and a decrease in their reliability as measures of the actual attainments of the pupils.

Part III

Typical Examination Papers Representing Superior, Average and Poor Students

A relatively small proportion of the teachers responded to the request to send examination papers representing superior, average and poor students. Only twenty sets of papers, including one complete class set, were secured. Under remarks some

teachers gave as reasons for failure to comply in this matter, "papers returned to students for correction," "papers kept on permanent file," and "not available at present." Others, undoubtedly, dodged the issue by ignoring this part of the questionnaire.

A discussion of the marking systems used does not fall within the scope of this investigation. The exact standards fixed by the different teachers concerned could not be ascertained for all questions. But wherever in concrete particulars this was possible, inconsistencies were discovered in their application. This may have been due either to lack of definite formulation of such standards and change during the process of scoring, or difficulty in applying standards and in distinguishing between closely related degrees of merit.

The following examples illustrate errors and inconsistencies in the grading of the representative examination papers.

A. Answers partly or entirely wrong scored as right

(Q. stands for question; A. stands for answer; C. stands for comment.)

1. Q. Why is it possible for an iron ship to float?
   A. It is possible for an iron ship to float because the weight of a ship and its cargo is less than the weight of a volume of water displaced.
   C. The term "a" was probably intended to mean "an equal." The ship and cargo displace a volume of water equal to and not less than their combined weight.
2. Q. What are the conditions necessary for the formation of dew?
   A. 1. This vapor soon a cooled form tinny drops right above the ground. Dew forms and not rained or rises. This is the reason you can pick up a board off the ground and it is wet on both sides.
   A. 2. When the air is just a little below saturation dew will form.
   C. The first answer evinces an imperfect comprehension of the phenomenon. The second answer is entirely wrong. Air must be more than saturated to have dew formation.

3. Q. What are enzymes and vitamines?
   A. 1. Enzymes are small cells in food and is impure.
   A. 2. Enzymes are small cells which carry the impurities of the blood to the lungs and give if off for oxygen.
   A. 3. Vitamines are impurities in food which are taken out by cooking.
   C. Enzymes and vitamines are not impurities.
4. Q. Define buoyancy.
   A. 1. Buoyancy is the process of any object being buoyed up by the force of its own weight.
   C. This does not show a clear conception of buoyancy.

B. Inconsistencies in Scoring

(Q. stands for question; A. stands for answer; C. stands for comment.)

1. Q. What is General Science?
   A. 1. General Science is anything in the world that one can study about.
   A. 2. General Science is the study of all things in the universe.
   C. The first answer was regarded as perfect and received 10 or full credit. The second answer, which is at least as good, for some unaccountable reason received only 7.
2. Q. Name three steps in the scientific method.
   A. 1. a. Collection of data.
   b. Logical arrangement of data.
   c. Arriving at conclusion.
   A. 2. a. Get all facts concerning problems you are dealing with.
   b. Arrange facts in order.
   c. Come to some conclusion or application of problem.
   C. The first answer was graded 10. The second answer which is perhaps slightly better, received a grade of 8.
3. Q. What is meant by organic cycle?
   A. 1. An organic cycle is where one substance leads into another and this other substance leads to another, and pretty soon it leads back to the first substance.

A. 2. The organic cycle shows how all things begin with inorganic matter, then all come back to it as "Dust thou art, to dust thou shalt return."

C. The first answer was graded 5, and the second answer was graded 10, although neither one gives an adequate account of the organic cycle. They both contain practically the same elements except for the Biblical quotation in the second one.

4. Q. What important things do leaves do?

A. 1. Leaves take in oxygen.

A. 2. Leaves take in oxygen and sunshine.

A. 3. Leaves take in carbon from the air.

C. The chief functions of the leaves include the manufacture of starch out of water from the soil and carbon dioxide from the air, the taking in of air for oxidation, the throwing off of carbon dioxide in respiration, and the excretion of water and other wastes.

On this basis it is difficult to understand why the first answer is marked 5; the second, 3; and the third, 8. The second answer received less than the first answer although it repeats what is there given and adds another essential fact. The third answer which names carbon received more credit than the first answer which names oxygen, another element just as important.

Conclusions

1. The nature of the conventional examination paper limits the application of objective standards in marking.
2. Errors and inconsistencies in the scoring of the papers are not uncommon.
3. The scoring of the papers is strongly subjective.

Summary

1. General Science is taught usually in the ninth school year in mixed classes of boys and girls.
2. Written tests are held generally at irregular intervals depending upon the completion of major topics. Final examinations are given in most high schools.

3. The usual number of questions in an examination is ten.
4. The time limits vary from 40 to 45 minutes for term tests, to one, two, or even three hours for final examinations.
5. The majority of the teachers write the questions on the board. Other teachers mimeograph or dictate the questions. In a few cases final examinations are printed.
6. English, spelling, penmanship, neatness and other factors, outside of the subject-matter proper, directly or indirectly influence the marks assigned.
7. About one-half of the teachers weight the questions on the basis of their relative importance, difficulty or complexity.
8. Conventional examinations vary markedly in length. Some are unreasonably long and necessitate a considerable amount of writing.
9. The questions are sometimes indefinite, poorly worded and otherwise imperfect in construction.
10. The scoring of the papers is strongly subjective.

CHAPTER III

THE MEASUREMENT OF ACHIEVEMENT IN GENERAL SCIENCE BY MEANS OF WRITTEN EXAMINATIONS

A brief statement of the objectives of General Science and the material of instruction for their realization should precede the discussion of measuring attainment in this field. The leading aims in the teaching of introductory courses in science are:—first, retention and control of a large body of elementary scientific facts and principles of significance in the home, school and community, without restriction in scope to logically organized fields of study and directly useful to practically all pupils; second, appreciation and intelligent understanding of the relation between man and his natural environment; third, study of the developments of science and their applications in modern economic and social life; and fourth, the development of a scientific attitude and scientific methods of procedure in dealing with problems of every-day life.

It is unlikely that there will ever be a uniformly recognized standardization of the content in General Science comparable to that found in courses in mathematics, Latin, history, physics, chemistry and other subjects of long standing in the high school. The newness of General Science, the growing realization that secondary school courses of study should respond more quickly to social and economic changes and to the differentiated needs of both society and the individual, and the almost inexhaustible material available make it seem probable that teachers will not agree on topics to be incorporated nor upon methods of instruction.

The power to apply significant facts and principles of everyday natural phenomena and to exercise good judgment in regard to affairs of a scientific nature in practical life situations, rather than mere ability to reproduce memorized textual material, are of fundamental educational importance. Therefore, the written examination as a measure of accomplishment should test dynamic knowledge or the ability to utilize facts, rather than static knowl-

edge or the ability to store up the memory with academic information, and must be objective, that is, within a small margin of error, yield the same results in the hands of any marker.

In the first chapter it was shown that the conventional examination is noticeably subjective and the marks assigned by teachers are generally unreliable. The development of standardized achievement tests, which do meet the requirements relative to objectivity and preciseness, made it desirable to consider the construction of a similar test in General Science.

The advantages of standardized tests and scales, based on 50 different books and articles in educational magazines, have been admirably summarized by Capps.[1] A condensed form of his analysis follows:

ADVANTAGES OF STANDARDIZED TESTS AND SCALES

A. Classification of Pupils.
   1. To detect the superior, mediocre, and weak students for purposes of classification, and reclassification.
   2. To discover the special difficulties of individuals.

B. Organization.
   1. To discover definite methods of improving a program.

C. Course of Study.
   1. To establish definite objective standards of achievement.
   2. To determine the subjects which need emphasis.
   3. To determine the relative value of textbooks on the basis of results secured.
   4. To determine minimal essentials.

D. Methods of Instruction.
   1. To diagnose the work of individual pupils.
   2. To discover the efficiency of various methods.
   3. To stimulate the invention of new devices and improvement of methods.
   4. To establish in the teacher a scientific attitude.
   5. To determine where to place the emphasis in instruction.
   6. To determine the type of drill needed.

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[1] Capps, A. G.: "The Functions of Tests and Scales as Found in Recent Educational Literature," Journal of Educational Research, 6: 204–8, October, 1922.

7. To enable teachers to give recognition in proportion to merit.
8. To enable pupils to know definitely what is expected of them.

E. Time devoted to Subdivisions of Subject.

1. To guide in the proper apportionment of time to various topics.
2. To aid in finding out how much time is required for a specific task.

F. Supervision.

1. To measure educational products quantitatively and qualitatively.
2. To measure the progressive increase in achievement.
3. To obtain a closer checking up of results.
4. To diagnose the work of individual pupils.

However, Capps neglected to make a similar search of educational literature for disadvantages of standardized tests and scales. Under the same plan of organization, their limitations, with particular reference to secondary school subjects, follow:

Disadvantages of Standardized Tests and Scales.

A. Classification of Pupils.

1. Our classification of pupils will depend upon the criteria used. Standardized tests and scales do not furnish us with instruments, readily adjustable to changing conceptions of the aims, the content, and methods of instruction, by means of which we may be able to detect the superior, mediocre and weak students for the purpose of grouping them by abilities.

B. Organization.

1. Adaptation of material of instruction to the changing needs of the community, to the diversified needs of the individual pupils, and to special local conditions, are not measured by standardized tests and scales.

C. Course of Study.

1. There are more important values in most high school subjects which are intangible, variable and cannot be standardized, than the mastery of the tool elements or minimum essentials which can be standardized. Few if any educational tests are broad enough in scope to test the whole field in any subject.

2. Standard tests and scales are not adapted to specific, local curricula, and do not take into account differences in content covered by the class, relative amount of time spent on different topics, the teaching emphasis, and particular methods employed.

3. The application rather than the mastery of facts and principles are important aims. This cannot be standardized.

4. Standard tests and scales tend to produce a uniform, static, deadening course of study, and restrict its responsiveness to changing social and economic conditions.

D. Methods of Introduction.

1. Teaching is likely to be influenced. Pupils are often coached to make high marks in the tests, and the results are in some cases padded, thereby lessening the realization of desirable aims and objectives.

E. Time devoted to Topics of Subject.

1. Limitation of the time to be devoted to different topics would interfere with the realization of aims referred to under organization and courses of study.

F. Supervision.

1. Standardized tests and scales do not recognize the personality of the teacher, the teaching emphasis, and special conditions.

2. They are more useful as supervisory than as teaching devices.

3. They are more adapted to the tool subjects in the elementary school than to subjects in the secondary school.

4. The tool elements and not the practical values of the subject are tested. Therefore, a low mark would not necessarily mean that the more important values of the subject have not been attained.

General Consideration of the New Tests in General Science

The new tests in General Science were devised in order to overcome the disadvantages of standardized tests and scales and, at the same time, retain most of their advantages. They were modeled after the best of our group tests of general intelligence and other objective tests and the new type of examination given

to students in the required freshman course in Contemporary Civilization at Columbia University. Although their construction was specifically adapted to General Science, the general scheme is applicable to many other high-school subjects.

In one part of the examination there were an equal number of true and false statements arranged in a haphazard order. The directing of attention to false statements did not constitute a violation of fundamental pedagogical principles because accurate conceptions had been taught first. The students were instructed to indicate which of them were true and which were false, and advised strongly against guessing. This was intended to test judgment based on specific material drilled upon in the classroom.

A second part of the examination involved the completion principle, mainly a quantitative application of scientific facts and laws. The answers were not suggested. It was designed chiefly to bring into action memory of recall.

The third and fourth parts of the examination contained incomplete statements and a series of word, phrase or sentence answers, only one of which was correct. It was planned to bring about the functioning of recognition memory. Most psychologists agree that in every-day life this type of memory is mostly used and is of more importance practically than memory of recall. Here any guessing by the pupils was probably largely intellectual, the result of unconscious cerebration based on what Dr. Yocum calls impressionistic retention and recall of material taught, or due to experiences outside of the school. Furthermore, it cannot be said that the simple nature of the responses necessarily implies that the mental processes tested are likewise of a simple nature, and that they fail to measure organized, systematic reasoning, for as Toops maintains,

"Psychologically, there is no reason why the results of a complicated thought process cannot be indicated by a simple one-word answer response on the part of the subject."[2]

A fifth part of the examination consisted of a reading test in science on a very small scale. An extract was reproduced from a book or scientific magazine, and several suggested answers

[2] Toops, H. A.: Trade Tests in Education, Teachers College, Columbia University Contributions to Education, No. 115, 1921, p. 61.

followed, only one of which was correct. It was designed to test ability to comprehend easy scientific material not previously taught, and to diagnose in a limited way the power to continue progress in this field without formal instruction.

The sixth and last part of the examination contained diagrams, chiefly of simple mechanical devices. Some of these were correct, to be so designated by the pupils, and others either had omissions or inaccuracies for correction. These diagrams were intended to gauge their ability to visualize applications of scientific facts and principles. The response in each case was narrowed down to symbolic representation by means of a line, curve or analogous unitary scoring-point in order to render possible objective measurement.

To generalize, the student usually responded by making a check mark, underscoring a word or phrase, writing a number, or adding a simple symbol on diagrams. There was a minimum of the mechanics of writing and of difficult mathematical computations and, it is hoped, a maximum of reasoning. The aim was chiefly to construct a battery of tests that would measure objectively the various phases of accomplishment in General Science, dissociated so far as practicable from the operation of factors like English, penmanship, spelling and drawing. In proportion as our educational measurements deal with unitary products of the teaching process and evaluated in terms of definable elements, the more refined and precise they will become. Of course, achievement in General Science is not an elementary thing, but the abilities called forth by the new tests are certainly less complex and therefore can be measured more accurately than in the case of the conventional tests.

It is hoped that the new type of test will provide teachers with a fairly reliable instrument for the purpose of measuring educational products, readily adjustable to the content, methods of instruction, and teaching emphasis, and will supplement and not supplant standardized tests and scales of minimum essentials in school subjects.

Summary

1. The written examination should measure accomplishment in subject matter based primarily on realization of fundamental educational aims and objectives.

2. It is unlikely that the course of study and the methods of instruction in General Science will ever become standardized.

3. Standardized tests and scales do meet the requirements relative to objectivity and preciseness and have many other advantages over the conventional tests. But they also have disadvantages limiting their usefulness.

4. New tests were devised in order to overcome the disadvantages of standardized tests and scales and, at the same time, retain most of their advantages.

5. It is hoped that the new type of test will provide teachers with a fairly reliable instrument for the purpose of measuring educational products, readily adjustable to the content, methods of instruction and teaching emphasis.

6. It is intended that the new tests should supplement and not supplant standardized tests and scales of the minimum essentials in school subjects.

CHAPTER IV

AN OUTLINE OF THE EXPERIMENT

The experiment was carried out in the West Philadelphia High School for Boys. It extended over two successive terms with two separate groups of students taking General Science, offered in the first half of the ninth year. Six classes during the first term and five classes during the second term, a total of 291 boys, took the tests. "General Science" by Caldwell and Eikenberry served as the text-book and general guide for the recitations and lecture demonstrations by the instructor. Four periods a week were devoted to the subject. There were no facilities for individual laboratory work by the students.

General intelligence as indicated by two different mental examinations of recognized standing is probably more dependable than that based solely on one. For this reason, both the Terman Group Tests of Mental Ability, Form A, and the Army Alpha Intelligence Examination, Form 9, were given to the pupils. This was followed by a parallel series of three conventional and three new types of tests in General Science, both covering practically identical content and progressively cumulative in nature, for the purpose of determining their relative advantage and disadvantages as measures of achievement.

The Conventional Tests in General Science

1. Construction

Most of the questions were selected from the sample sets sent along with the questionnaires, modified somewhat wherever necessary in order to make them conform to the material of instruction as taught. The rest of the questions were based on those used prior to the beginning of the experiment, reconstructed so as to facilitate administration and scoring.

2. Administration

Whenever two classes came on consecutive periods the same examinations were used. Otherwise they were different. But to insure a fair sampling of the most important topics overlapping and partial duplication of questions were unavoidable. The questions were written on the board and the boys were permitted to answer them either in pencil or in ink. The time limit was 45 minutes.

3. Scoring

The marking system was arbitrary. With a few exceptions, the questions were arranged so that a perfect answer, as judged by predetermined standards, would comprise either 1, 2, 4 or 8 key-ideas. In like manner, the elements to be incorporated in diagrams were decided upon in advance. Every question was assigned a value of eight. The number of unit-points expected in the answer was divided into eight and the product was the respective value of each element in the particular question. Problems were rated one-half for principle and one-half for correct solution. The questions asked in all the conventional examinations and the answer-keys will be found in the Appendix, Sections 2 and 3.

The New Tests in General Science

1. Construction

Several sources were utilized in gathering material for the questions. During the term good questions used in the class-room were recorded. Some of these were suggested by answers of the pupils in oral recitations. Others were prompted by their questions. In addition, some questions for discussion found in General Science textbooks proved suitable after modification. As far as possible, significant parts of the topics taught, particularly the most important dynamic aspects, were chosen. Enough material was thus assembled to make a test about three or four times the length of the one actually formulated. Then by a process of selection this was cut down so as to cover three mimeographed sheets. Each form was cumulative in character, with emphasis on the content most recently taken up in class.

It was intended to make the questions and statements clear, brief and in the affirmative form so far as practicable. They represented all degrees of difficulty, but no attempt was made to arrange them in a scale on that basis. The order of the separate sections of the tests was entirely arbitrary and dictated by convenience of spacing on the sheets, and other considerations that seemed rational. The general organization and the leading aims of the new tests as a whole and of the sub-parts have been discussed in the previous chapter.

2. Administration

The examination was administered in a uniform manner to all classes. The three mimeographed sheets comprising each new test were clipped together in the proper order in advance of their distribution to the pupils. Definite instructions were read regarding what was to be done, and methods of work.[1] The time was apportioned among the different parts of the tests so as to have the boys attempt all of them for a certain portion of the total time. The actual time spent in the answering of questions in the different forms of the new tests varied from 25 to 30 minutes.

3. Scoring

The marking scheme chosen for the scoring of the new tests was influenced by the impossibility of scientifically deriving relative weights for the different questions based on a sufficiently large number of cases, and the results of several recent investigations bearing on the general, practical worth-whileness of such a procedure. Charters[2] made a careful study of approximately 3100 seventh and eighth-grade pupils using his Grammar Scale on Pronouns, and found that the coefficient of correlation between the rating determined on the basis of unequal and equal weighted scores for each item was slightly over 0.901. Therefore, he felt justified in discarding the plan of relative weights according to difficulty of the questions previously scientifically established, in order to decrease the labor of counting up the total score.

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[1] The directions are given verbatim in connection with the New Tests reproduced later in this chapter.

[2] Charters, W. W.: "Constructing a Language and Grammar Scale," The Journal of Educational Research, 1:249-57, April, 1920.

Douglass and Spencer[3] administered the Douglass Standardized Diagnostic Tests for the fundamentals of First Year Algebra to 25 ninth-grade pupils in the University High School of The University of Oregon and the correlation between the weighted and unweighted scores for the sub-parts of this test, computed separately both by the Pearson Method of Paired Measures and the Rugg Device for Grouping, ranged from .961 to .999. A similar experiment conducted with a seventh grade class in the Ashland (Oregon) Junior High School by the same men with the Henmon Latin Test A, the Gregory Test for Language and the Monroe Standardized Silent Reading Test, given to 11, 30 and 32 pupils, respectively, likewise, yielded correlations surprisingly high, varying from .996 to .993, or very close to unity.

Monroe in his comparison of weighted and unweighted scores in a spelling test given to 306 fifth grade pupils in the Virginia survey reported a coefficient of correlation of .96 between weighted and unweighted scores and, therefore, properly concluded that "These facts do not necessarily mean that scores in terms of the number of exercises done correctly are as accurate descriptions of the performances of pupils as weighted scores or scores in terms of the level of difficulty reached. The facts, however, do show very clearly that the difference between weighted and unweighted scores are slight; and since it is doubtful whether weighted scores are more accurate, it seems to be justifiable to describe the performances of pupils in terms of the number of exercises done correctly."[4]

Accordingly, it was felt empirically reasonable to assign a value of 1 unit for each correct answer in the new tests. Each item was counted either as right or wrong and no partial credits were given. With the exception of the true-false tests, in which the score was the number of rights minus the number of wrongs and no negative scores given, the score was the number of rights. Improvised card-board stencils facilitated the scoring of the tests.

The new tests and instructions follow. The answer-keys will be found in the Appendix, Section 4.

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[3] Douglass, H. R. and Spencer, P. L.: "Is it Necessary to Weight Exercises in Standard Tests?" The Journal of Educational Psychology, 4: 109-112, February, 1923.

[4] Monroe, W. S.: "The Description of the Performances of Pupils on Exercises of Varying Difficulty." School and Society, 15: 341-3, March 25, 1922, p. 342.

General Science Examination

New 1

Part A.

1. If a barometer is carried up a mountain the mercury column drops about 0.1 of an inch for every 90–100 feet of elevation.
2. The Fahrenheit degree is larger than a Centigrade degree.
3. Isobars are lines connecting regions of the same temperature.
4. The reading of the barometer rises as a low area approaches any given region and falls as it passes.
5. After the air is saturated, if we raise the temperature, the air becomes unsaturated, although it was saturated at the lower temperature.
6. Air laden with dust becomes heated more rapidly than clean air.
7. Cold air is not so dense as warm air.
8. Water vapor is lighter than air.
9. The temperature of the air at its point of saturation is called the dew point.
10. All substances contract when heated and expand when cooled.

Part B.

1. The weight of air resting on an object 2 x 2 inches is . . . . . 4 ounces . . . . . 16 grams . . . . . 60 lbs. . . . . 60 cubic inches.
2. If air at a temperature of 26 degrees Centigrade actually holds 6 grams of water vapor per cubic meter and can hold 24 grams at the same temperature if saturated, then the relative humidity is . . . . . 50 grams . . . . . 25% . . . . . 50% . . . . . 25 grams per cubic meter . . . . .
3. A high pressure area is called . . . . . thunderstorm . . . . . cyclone . . . . . moonsoon . . . . . anticyclone . . . . . tornado . . . . .
4. At an elevation of about 4 miles the mercurial barometer will record . . . . . 15 inches . . . . . 30 inches . . . . . 15 lbs. . . . . 76 cm . . . . .
5. The changing of water vapor to the liquid form is called . . . . . evaporation . . . . . diffusion . . . . . expansion . . . . .

Part C.

1. Place a stopper in an empty bottle and warm the bottle. Now plunge it into a basin of cold water. Drops of moisture collect on the inside of the bottle. This experiment proves that
   a. Condensation of water occurs when air is cooled.
   b. Air weighs less per cubic inch than cold air.
   c. Evaporation of water may be hastened by cold.
   d. The bottle does not expand so much as the water on being heated.
2. The body is not crushed by the pressure of the air because
   a. The body is strong enough to resist the air pressure.
   b. We are used to the air pressure and do not mind it.
   c. The air pressure is exerted not simply downward but equally in all directions.
   d. The internal pressure of the body (blood) is equal to the pressure of the air.
3. Direct rays give more warmth than indirect rays because
   a. The rays striking the equator are warmer than those further north or south of the equator.
   b. The sun is nearer the equator than places north or south of it.
   c. Direct rays warm relatively larger areas than indirect rays.
   d. The air is warmer at the equator than in other parts of the earth.
4. Water will evaporate from a lake in Arizona more quickly than in New York because
   a. There are larger lakes in Arizona than in New York.
   b. The air is drier in Arizona than in New York.
   c. The relative humidity is higher in Arizona than in New York.
   d. The air pressure is lower in Arizona than in New York.
5. Why is it difficult to drink from a small mouthed bottle?
   a. It is not convenient to drink from a small necked bottle.
   b. The air cannot get into the bottle readily to replace the water.

c. The water cannot get out of the bottle readily because of the small passageway.
d. Air and water cannot occupy the same space at the same time.

Part D.

1. Air pressure is very useful to us. When we wish to remove the dirt from our carpet, we remove the air from the vacuum cleaner by a motor and fan, and as the air rushes in to fill the place from which the air was removed, it carries the dust and dirt along with it.
   a. The motor of the electric vacuum cleaner sucks the dirt up from the floor.
   b. A vacuum cleaner cleans a vacuum very efficiently.
   c. The dust and dirt are removed because air rushes in to fill in the vacuum produced and carries the other substances along with it.
   d. A vacuum is a space where there is very little air or a space entirely devoid of matter.
2. Thunderstorms usually occur in the southerly part of a cyclone during warm weather and in the warmer part of the day, but they may occur even in winter. They move eastward across the country at a rate of from twenty to fifty miles per hour and may affect a region many miles wide or be restricted to a width of a fraction of a mile.
   a. Thunderstorms are usually associated with low pressure areas.
   b. In cyclones the movement of the air is in a clockwise direction.
   c. Thunderstorms cannot occur in the winter.
   d. Thunderstorms may occur in the northwestern part of a cyclone.
3. In laying the foundations of bridge piers and other structures which must rest below water level, it is common for the laborers to work in a large steel chamber which has no floor and which rests upon the bottom of the lake or river. This is called a caisson. The water is kept out of the caisson by the use of air pumps which force air into it with suf-

ficient pressure to overcome the pressure of the water. The entrance and exit of workmen without allowing the escape of the air in the caisson is made possible by means of a tubular passageway which leads to the bottom of the caisson.

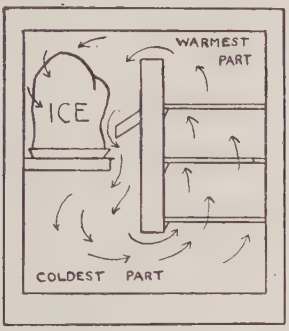
a. The interior of the caisson has reduced air pressure.
b. The water is kept out by the use of vacuum pumps.
c. The caisson and the diving bell work on the same principle.
d. The water is kept out by forcing in air under pressure into the caisson.

4. The aneroid barometer in its simplest form is a metal box from which a large part of the air has been removed. The cover will bend slightly with changes of pressure of the atmosphere. By a series of levers the extent of movements of the cover of the box is multiplied and represented by a pointer on a dial.
   a. The aneroid barometer indicates pressure by changes in the height of the mercury column.
   b. The interior of the aneroid barometer is an almost complete vacuum.
   c. The aneroid barometer is more reliable than the mercurial barometer.
   d. The movements of the pointer on the dial is controlled by a series of levers within the aneroid barometer.

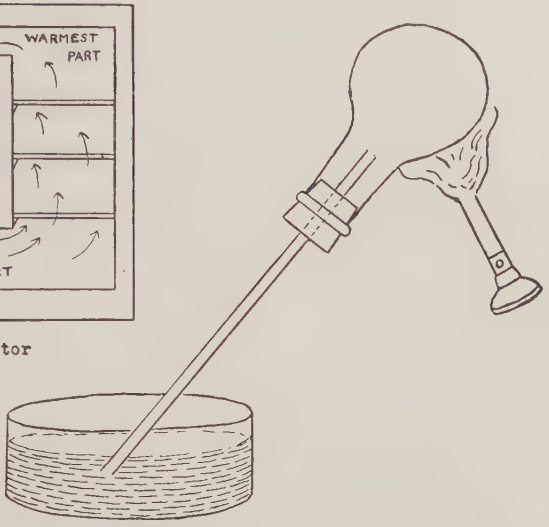
Part E.

1. Arrange the following parts of a report of an experiment in the proper order by a number after each—Discussion . . . . . Materials . . . . . Purpose . . . . . Conclusions . . . . . Directions . . . . .
2. Using the formula $C = 5/9(F-32)$ change 68 degrees F. to C. degrees.

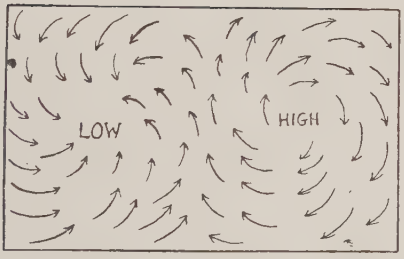
Part F.



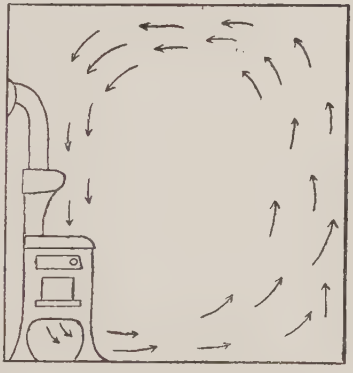
1. Refrigerator



2. Expansion of Gases



3. Deflection of Air Currents in Northern Hemisphere



4. Convection Currents in Room

General Science Examination

New 2

Part A.

1. The mechanical advantage of any pulley is equal to 4.
2. Our everyday work and the work of the world would be done much better if all friction were eliminated.

3. Air is a mixture of oxygen, nitrogen, argon, carbon dioxide and other gases.
4. Freezing of water is a chemical change.
5. A machine cannot create any energy nor can it do work unless work is done upon it.
6. The land cools more rapidly than the water.
7. All bodies immersed in any fluid are buoyed up with a force equal to the weight of the water displaced.
8. Crushing of rock is a physical change.
9. A siphon will work better in a vacuum than in air.
10. Heating a body decreases its density and cooling a body increases its density.

Part B.

1. If 3/4 of the force applied to a machine is available for useful work, while 1/4 is wasted in overcoming friction, the efficiency is . . . . .
2. If a person weighing 100 lbs. walks upstairs to a height of 20 feet he does . . . . . of work.
3. A boat which has a displacement of 100,000 c.c. of water weighs . . . . . grams.
4. A boy pulling with a force of 50 lbs. at the end of a rope of a pulley system, having 8 sheaves and 8 turns of rope, could raise . . . . . lbs.
5. On a certain day the air had only 1/2 enough moisture in it to make it saturated. The relative humidity, therefore was . . . . .

Part C.

1. The odor of ammonia becomes noticeable throughout a room soon after a bottle of ammonia water is uncorked because of—evaporation, distillation, transpiration, diffusion, condensation.
2. Balloons are filled with—compressed air, oxygen, steam, nitrogen, helium.
3. The name of the instrument used to measure the pressure of the atmosphere is—thermometer, barometer, rain gauge, isobar, isotherm.

4. A block of wood 8 inches deep sinks 4 inches in water. Its specific gravity is therefore—5 grams per c.c., 10 ounces, .5, 4 ft. lbs., 32 grams.
5. What is the name of the process by which the sun transmits heat to the earth? Radiation, saturation, conduction, buoyancy, convection.
6. On the Fahrenheit Thermometer how many degrees are there between the freezing and the boiling points? 212 degrees, 100 degrees, 32 degrees, 180 degrees, 120 degrees.
7. The smallest possible particle of a substance like water, table salt (sodium chloride), carbon dioxide, is—a molecule, an atom, an ounce, a gram, 1/1000 of a gram.
8. Water having in solution minerals like lime (calcium bicarbonate), sulphates and chlorides of calcium and magnesium, etc. is called—freezing mixture, soft water, impure water, pure water, hard water.
9. Which of the following substances is the best conductor of heat,—iron, wood, stone, air, copper?
10. Which of the following chemicals may be used to obtain a supply of nitrogen—ammonium chloride and manganese dioxide, potassium chlorate and manganese dioxide, sodium nitrite and ammonium chloride, sodium nitrate and sodium chloride, hydrochloric acid and marble.

Part D.

1. Why does sprinkling the streets on a hot day in summer cool the surrounding atmosphere?
   a. The water is cooler than the air.
   b. The evaporation of the water takes up some of the heat in the air.
   c. The water condenses and thus cools the air.
   d. The air becomes moist and therefore is cooler.
2. Why are flatiron handles made of wood?
   a. Wood is a poor conductor of heat.
   b. Wooden handles are cheaper than iron handles.
   c. Iron is a poorer conductor of heat than wood.
   d. Iron feels colder to the hand than wood.
3. Why do people say, "It is going to rain when the kettle boils easy?"

a. The relative humidity is high.
b. Atmospheric pressure is high just before a rainstorm.
c. Boiling point of water is lowered by a decrease of atmospheric pressure, due to the approach of a cyclone.
d. The temperature of the air is warmer just before a rainstorm.

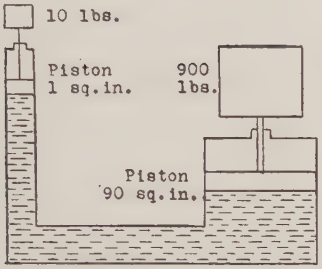
4. Why does the reading of a thermometer drop when first placed in hot water?
   a. The thermometer is cooler than the water.
   b. The mercury expands more than the glass of the tube.
   c. The mercury is a better conductor of heat than the glass.
   d. The glass of the tube gets heated first and expands before the mercury.
5. Wet two small pieces of cloth; hang one in a dry battery jar and the other in a battery jar in which there is a small amount of water. Which piece of cloth dries the sooner?
   a. The one in the dry jar because evaporation goes on faster in dry air.
   b. The one in the dry jar because air in the dry jar is warmer.
   c. The one in the jar containing a little water because currents are produced.
   d. The one in the jar containing a little water because it is cooler than the other jar.

Part E.

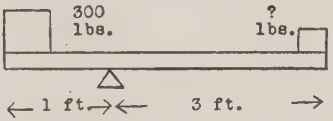
1. Take some finely ground salt and sugar and shake them together, and they become so inextricably mixed that only by an elaborate and tedious process could they be separated again. Yet they remain salt and sugar, and even if you dissolved them in water, they would still remain salt and sugar, each retaining its own peculiar qualities of color, taste, and so forth. They form merely a mechanical mixture, and not a chemical compound. Mix powdered sulphur and iron filings together, and apply heat to the mixture and at once the two substances combine to form a black material called iron sulphide, which is neither iron nor sulphur and has no resemblance to either.

a. Salt and sugar when heated form a chemical compound.
b. Salt and sugar in a finely divided condition form a mixture, but when dissolved in water they form a chemical compound.

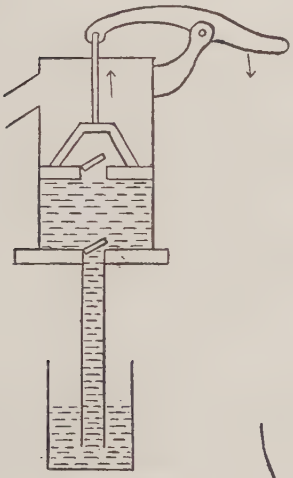
Part F.



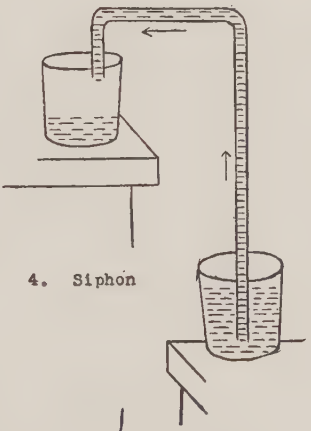
1. Hydraulic Press



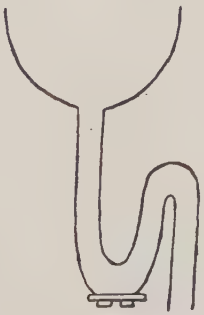
2. Lever



3. Lift Pump



4. Siphon



5. Trap of waste-water pipe

c. Powdered sulphur and iron filings change into a chemical compound which has different physical properties from either the sulphur or the iron when heat is applied to a mixture of these two substances.

d. When heat is applied to powdered sulphur and iron filings they combine and form a compound, but they can readily be separated again, and do not lose their properties as sulphur and iron, respectively.

e. Mixing salt and sugar no matter how thoroughly, nor dissolving them in water will cause the two substances to unite with one another and form a chemical compound.

General Science Examination

New 3

Part A.

1. T. F. Rotation of the earth from west to east causes the air in a cyclone to move counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere.
2. T. F. The atmosphere is a chemical combination of oxygen, nitrogen, carbon dioxide, water vapor, argon and other rare gases.
3. T. F. 180 degrees F. is warmer than 100 degrees C.
4. T. F. Sweetening tea or coffee with sugar is a physical change.
5. T. F. A mixture of salt and water will form ice at 4 degrees C.
6. T. F. The solar system is composed of the sun and the planets and satellites revolving around it.
7. T. F. We would feel more comfortable on a day with a relative humidity of 90% and temperature of 85 degrees F. than on a day with a relative humidity of 65% and the temperature 85 degrees F.
8. T. F. A sudden fall in the barometric reading indicates a sudden shower, or high winds, or both.
9. T. F. The weight of a cubic foot of water at 20 degrees C. is less than that of a cubic foot of water at 60 degrees C.
10. T. F. If 4 incandescent lamps were wired in series and one light went out, then all the lights would go out.

Part B.

1. If a man places a fulcrum 1 ft. from the end of a 6 ft. crowbar and presses down on the other end with a force equal to 100 lbs. he can raise ..... lbs.
2. To obtain a supply of pure oxygen we may use the following chemicals .....
3. Atmospheric pressure at the sea level is about ..... lbs. to the sq. in.
4. If the density of gold is 19.4 grams per c.c. then a cubic centimeter of gold would weigh ..... grams in water.
5. The moon is about ..... miles distant from the earth.
6. A man raising a weight of 50 lbs. a vertical height of 5 ft. does how much work? .....

Part C.

1. The sun is a—satellite, planet, star, nebula, comet.
2. The passage of the earth between the sun and the moon produces—an eclipse of the earth, sun-spots, new moon, eclipse of the moon, eclipse of the sun.
3. The temperature at which dew forms is called—dew point, humidity, diffusion, evaporation, condensation.
4. The resistance which opposes an effort to slide or roll one body over another is called—energy, friction, power, work, inertia.
5. We may obtain absolutely pure water for batteries by—boiling, adding sodium hypochlorite, filtration, electrolysis, distillation.
6. The unit used for measuring quantity of electricity is the —volt, ampere, ohm, watt, kilowatt.
7. The transference of heat from one point of a heated iron rod to the other end is called—convection, radiation, conduction, reflection, absorption.
8. If limewater is turned milky by a gas bubbling through it, that gas is—illuminating gas, oxygen, carbon dioxide, hydrogen, nitrogen.

Part D.

1. The planets in order of distance from the sun are:
   a. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.

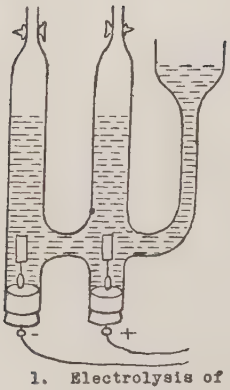
b. Mercury, Venus, Earth, Mars, Jupiter, Uranus, Saturn, Neptune.
c. Jupiter, Saturn, Neptune, Uranus, Earth, Venus, Mars, Mercury.
d. Earth, Jupiter, Mars, Mercury, Neptune, Saturn, Uranus, Venus.

2. An atom is:
   a. The smallest part of any substance like water.
   b. The unit parts of which molecules are composed.
   c. A certain impurity found in water.
   d. Small substance about the size of germs.
3. The boiling point of any liquid is:
   a. 212 degrees F. or 100 degrees C.
   b. The temperature at which it condenses.
   c. The temperature at which any liquid is changed into water vapor.
   d. The temperature at which a liquid changes into the corresponding gaseous form.
4. A chemical fire extinguisher helps to put fires out because:
   a. It is handy and always ready for use.
   b. It pours water on the fire.
   c. The carbon dioxide gas formed is a heavy gas and will not support combustion.
   d. Nitrogen gas is formed which does not support combustion.
5. An iceless refrigerator keeps food and water cool because:
   a. Evaporation of water removes heat from the interior.
   b. Heat of the outside cannot get in the refrigerator or cooler.
   c. The heat in the interior leaks out readily.
   d. The ice present cools the food and water.
6. Why are your feet colder when you are standing in melting snow than when you are standing in freezing snow?
   a. The day is colder when the snow melts.
   b. The shoes are poor conductors of heat.
   c. The melting of the snow requires heat which it gets from any convenient source.
   d. Freezing snow is colder than melting snow.

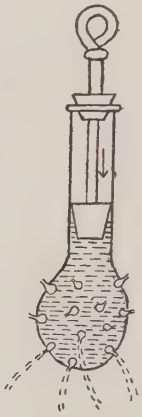
Part E.

1. A substance which conducts or transmits electricity readily is called a conductor, while a substance that does not is called an insulator or non-conductor. Silver, copper, aluminum, zinc, platinum, iron, nickel, tin, lead, carbon are examples of good conductors, while porcelain, wool, silk, glass, rubber, wood, shellac, dry air are examples of insulators or non-conductors.
   a. Rubber gloves render it safe for repair men to handle live wires.
   b. Silk, nickel, zinc, dry air are all insulators.
   c. Porcelain, wood, shellac, glass are all fair conductors.
   d. A platinum wire would conduct electricity readily.
2. When the roots of plants grow into crevices of rock, they often exert sufficient force to split it. Many lowly plants, such as lichens and mosses, grow upon the surfaces of rock, and the organic products (acids) formed by them assist in disintegrating the rock. When once a little broken rock and organic soil material has been formed, other plants and animals may then grow and may in their turn make further contributions to soil-making. Unless this soil is washed away, it may constantly increase in its depth and productivity.
   a. The action of plants is the only factor in soil formation.
   b. The growth of roots of plants into crevices of rocks often exerts enough force to cause particles of rock to break off and thus helps to form soil.
   c. Some plants like lichens and mosses form certain acids which assist in the disintegration of the rocks.
   d. The effect of plants and animals in soil formation is more marked in the winter months.

Part F.

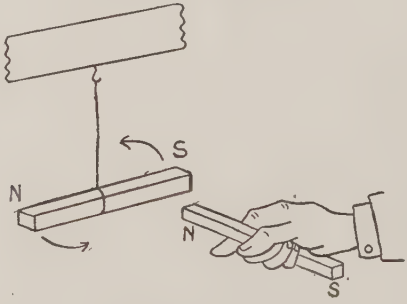


1. Electrolysis of Water.

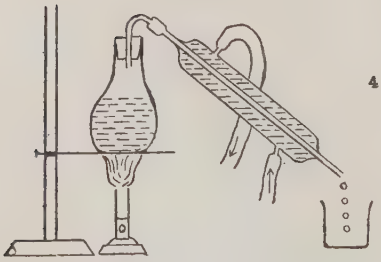


2. Transmission of Liquid Pressure (Pascal's Principle)

3. Incandescent Lamp



4. Effect of Unlike Poles of Magnets



5. Distillation of Water.

General Science Examination

New 4

Part A.

T. F. 1. When air is warmed the relative humidity drops and when cooled the relative humidity rises.

T. F. 2. Isobars are lines connecting regions of the same air pressure.

T. F. 3. A fall in the reading of the barometer indicates fair weather, and a rise in the reading indicates stormy weather.

T. F. 4. Ice and snow evaporate during cold winter weather.

T. F. 5. The higher the altitude the higher the reading of the barometer.

T. F. 6. Evaporation goes on more rapidly when the relative humidity is high than when the relative humidity is low.

T. F. 7. The weight of the mercury column in a barometer is equal to the weight of the air column of the same diameter as the mercury column, but extending up as high as the air goes.

T. F. 8. It is warmer in Philadelphia in July than in January because we are nearer to the sun in summer.

T. F. 9. The boiling point of a thermometer is determined by placing the instrument in hot water.

T. F. 10. The relative humidity at the dew point is 100%.

Part B.

1. The weight of air pressure on a book 5 x 8 inches is . . . . . lbs?
2. During a stormy day the reading of a mercurial barometer dropped 1.5 inches. A water barometer would have dropped . . . . . inches?
3. 40 degrees Centigrade equals . . . . . degrees Fahrenheit?
4. 140 degrees Fahrenheit equals . . . . . degrees Centigrade?
5. If air at 20 degrees Fahrenheit can hold 17.12 grams of water vapor when saturated, and the absolute humidity is 12.5 grams, the relative humidity is . . . . .

Part C.

1. A low pressure area is called—anticyclone, tornade, cyclone thunderstorm, hurricane.
2. The changing of a liquid to the corresponding gaseous form is called—evaporation, condensation, expansion, contraction, osmosis.

3. An instrument to measure temperature in degrees, is called —barometer, thermometer, caisson, manometer, barograph.
4. One-half of the atmosphere of the earth is within—100, 50, 200, 4, 10 miles of the surface of the earth.
5. The transference of heat from an iron rod, heated at one end, to the other end is called—convection, radiation, conduction, gravitation, diffusion.

Part D.

When a thunderstorm is raging, you are just about as safe in one part of your home as another. Yet there are a few danger spots. If you are in direct line between two good-sized metal objects, such as a steam radiator and an iron sink, or between either of these and a rainspout running up the side of the house, you may be struck by direct or induced flashes of lightning. In seeking an outlet to the ground, lightning has a tendency to jump between two such metallic bodies, rather than to take a direct course through non-conducting mediums. Steel-framed buildings are excellent conductors. They tend to relieve by silent discharge the electric strain always existing between earth and sky, during a thunderstorm. Sometimes they are struck, but the people inside them never know it.

1. The place where a wire clothes line enters a house may be a source of danger if one stands directly beneath a hanging lamp or globe suspended from the ceiling by a chain.
2. It is safe to take shelter out of doors if caught in a thunderstorm under an isolated tree.
3. Electricity and lightning are two entirely different substances.
4. Metallic substances are not good conductors of electricity.
5. One is absolutely safe in a thunderstorm if in a steel-framed building.

Part E.

1. What causes the noise when a thimble is suddenly removed from a wet finger?
   a. The air in the thimble escapes.
   b. Difficulty in removing the thimble.

c. The air rushes in to fill the vacuum produced.
d. Expansion of the air within the thimble.

2. A fountain pen leaks when it is nearly empty because
   a. There is air above the ink in the chamber.
   b. It is a cheap pen.
   c. It is not kept right side up in the pocket.
   d. The ink is of poor quality.
3. Why does a mist sometimes form upon a person's eyeglasses when he comes into a warm room from the street on a cold day?
   a. The warm air in contact with the cold glasses condenses into water vapor.
   b. The absolute humidity of the air in the room is less than that of the air in the street.
   c. Both sides of the eyeglasses are not of the same temperature.
   d. The cold glasses condenses some of the water vapor in the air in the room.
4. Why is it difficult to pour liquid through a funnel which fits tightly into the mouth of a jug or bottle?
   a. Air and water cannot occupy the same space.
   b. The air within the jug or bottle cannot escape readily.
   c. The mouth of the jug or bottle is not wide enough to permit much water to enter at one time.
   d. The funnel is not an efficient device for the purpose.
5. Why does a cake of ice in a refrigerator thaw more rapidly at the top than at the bottom?
   a. The upper part of the cake of ice cools the air more readily than the other parts of the ice, thereby melting more rapidly at the top.
   b. The upper part of the cake of ice is not so cold and hard as the other parts of the ice.
   c. The ice cools the air, colder air is heavier and falls and the warmer lighter air is forced into the upper part of the refrigerator.
   d. It is the most natural place for the ice to begin melting.
6. What are the conditions favorable to a deposit of dew?

a. Warm day, high relative humidity; drop in temperature at night.
b. Grass or rocks upon which dew may be deposited.
c. A rise in the absolute humidity during the night.
d. Clear cold windy day, and high reading of the barometer.

7. In the manufacturing of maple sugar, why are the pans for the evaporation of the water from the sap large and shallow?
   a. More sugar can be conveniently placed in large, shallow pans.
   b. Pans that are shallow are not likely to be easily upset.
   c. Heat is one of the factors in evaporation.
   d. A larger area is exposed to the air, increasing the rate of evaporation.
8. Why does 90 degrees F. in Arizona produce less discomfort than in the same temperature in New Jersey?
   a. Arizona has an average temperature much higher than that of New Jersey.
   b. The climate in Arizona is drier than in New Jersey, therefore perspiration cools the body more quickly and readily by evaporation.
   c. The people living in Arizona are more accustomed to high temperatures.
   d. Perspiration evaporates thereby cooling the air in contact with our bodies.

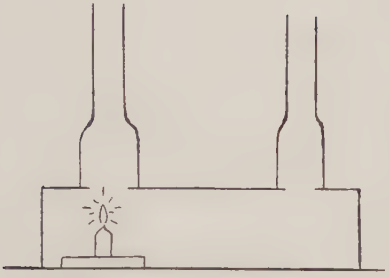
General Science Examination

New 5

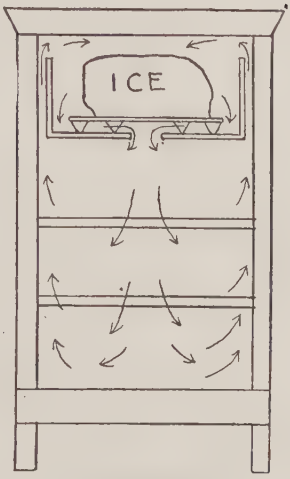
Part A.

1. T. F. A pulley is a rigid rod or bar free to turn about a fulcrum.
2. T. F. Nitrogen may be obtained by heating equal quantities of ammonium chloride and sodium nitrite dissolved in water.
3. T. F. Air supports combustion, therefore nitrogen, forming four-fifths of the air, must support combustion.

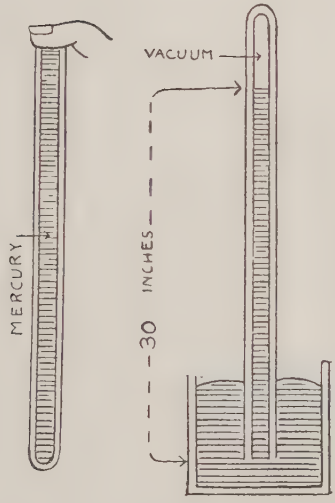
Part F.



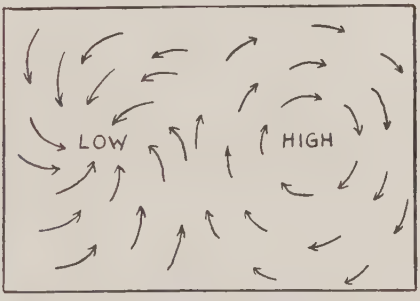
1. Convection Currents of Air



2. Refrigerator



3. Torricelli's Experiment



4. A low and high pressure area in the northern hemisphere

4. T. F. Buoyancy is an upward push or force only found in water and air.
5. T. F. A machine is an advantageous device because we get more work out of it than we put into it.
6. T. F. Water expands when cooled between 4 degrees C. and 0 degrees C.
7. T. F. Rolling friction is less than sliding friction.

8. T. F. All solids, liquids and gases expand at the same rate when heated, and contract at the same rate when cooled.
9. T. F. If salt is dissolved in water the boiling point is raised.
10. T. F. The relative humidity of the air may be found by using the wet and dry bulb thermometer.

Part B.

1. Change 60 degrees F. to C. degrees. .....
2. An object floats in water half-submerged, what is its density? .....
3. What is the atmospheric pressure per square inch 4 miles above the sea level? .....
4. How many grams of water vapor in 500 cubic meters of air at 20 degrees C (air can hold 17.12 grams per c.m.), if relative humidity is 60%? .....
5. If you are pulling with a force equal to 125 lbs. at the end of a rope in a set of 4 pulleys, how heavy a weight can you lift? (Ignore friction).....
6. How much work is done when a trunk weighing 120 lbs. is raised 3 feet? .....
7. A lever is 12 feet long. If a weight of 12 lbs. is at one end of the lever, 3 ft. from the fulcrum, how many lbs. will it balance at the other end of the lever? .....
8. What would 1 cubic centimeter of gold weigh in water if it weighs 19.4 grams per cubic centimeter in the air? .....
9. If the specific gravity of iron is 7.2, how much would 10 cubic centimeters of the substance weigh?.....
10. If you exert a force equal to 100 lbs., how many strands of rope must a set of pulleys have in order that you be able to raise a weight of 600 lbs.? (Ignore friction).....

Part C.

1. Illuminating gas is a—simple element, mixture of gases, chemical compound, hydrogen combined with another gas.
2. The melting of a piece of lead is called—chemical change, decomposition, contraction, physical change.
3. The ratio of the output of useful work accomplished to the input or total work put into a machine is called—mechanical advantage, efficiency, force, resistance.

4. We can obtain a supply of oxygen by heating the following substances—potassium chlorite and manganese dioxide, potassium chloride and manganese dioxite, potassium chlorate and manganese dioxide, potassium chlorate and magnesium dioxide.
5. The most practical plan of purifying the water supply of a large city is—distillation, boiling, filtration-plant, house-filter.
6. How high can we pump water with a lift pump practically? 30 centimeters, 30 feet, 100 feet, any height.
7. The process of changing a liquid to the gaseous form by applying heat and then condensing the vapor to a liquid is called—distillation, filtration, evaporation, boiling.
8. An instrument used to measure atmospheric pressure is called a—thermometer, manometer, caisson, barometer.

Part D.

"We must increase the efficiency of power production from coal, oil, gas, etc., by utilizing a higher percentage of its chemical energy, which we now waste, and turn this into productive power. The future holds great promises in this direction also. Under present-day methods of converting the chemical energy of coal over into electric energy, we obtain only 10 to 20 per cent. The remainder is thrown away as heat. We use enough coal in a year to equal in bulk the Great Wall of China. With the chemical energy represented by another year's production we could raise that great mass up into space for a distance of 200 miles. It is clear, therefore, what the perfection of methods that would result in the utilization of a greater percentage of the coal we burn would mean to industry. What is true of coal is true of oil and gas. Some day we shall come much nearer to obtaining 100% efficiency from them." (Steinmetz.)

1. Some day we will obtain an efficiency of 100% in our methods of transformation of energy.
2. In power production from coal, oil, gas, etc., we utilize a high percentage of its chemical energy.
3. We waste 80% or more of the energy in the form of heat, in changing the chemical energy of coal into electric energy.

4. A year's output from our coal mines equals in bulk the Great Wall of China extended up into space about 200 miles.

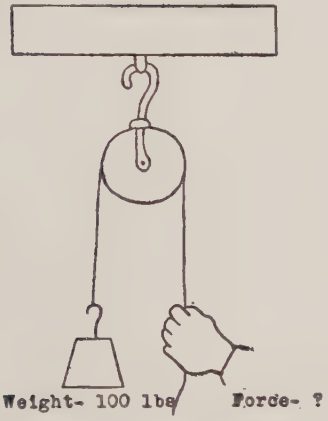
Part E.

1. Why does iron rust?
   a. There is a chemical combination between oxygen in the air and iron producing iron oxide.
   b. The water vapor in the air combines with the iron.
   c. Iron rusts when it does not have a coat of paint.
   d. Moisture always causes rusting.
2. How will a substance which floats in water 1/2 submerged, behave in oil? (Density of oil is .9 grams per cubic centimeter.)
   a. It will not sink as deep as in the water since the oil has a density less than that of water.
   b. It will sink deeper in the oil, until it displaces its own weight in the oil.
   c. It will sink to the bottom in the oil.
   d. It will also float 1/2 way submerged in the oil.
3. What is the difference between the oxygen present in the air and the oxygen present in water?
   a. Water is a mixture of 2 gases, O one part and H two parts; the O in the air is combined with N and other gases.
   b. The oxygen in the air is purer than the oxygen in water.
   c. There is more oxygen present in the air than in water.
   d. In the air oxygen is mixed with nitrogen and other gases; in water one part of oxygen is combined with two parts of hydrogen.
4. Why does a lamp chimney become coated with water vapor on the inside when a lamp is lighted? Why does this vapor disappear in a short time?
   a. The heat causes expansion of the air and water vapor is deposited. This soon disappears on account of evaporation.
   b. The cold glass causes condensation of water vapor in the air within the chimney until it becomes warm.
   c. Hydrogen, resulting from the breaking up of the oil, combines with oxygen in the air forming water-vapor.

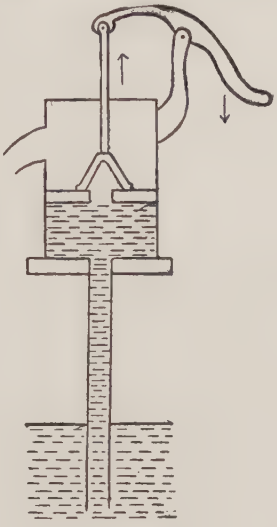
This soon evaporates on account of the heat produced by the flame.

d. Convection currents of air are produced; water vapor deposited on the inside of the lamp chimney, which later evaporates.

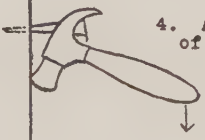
Part F.



1. Single Fixed Pulley

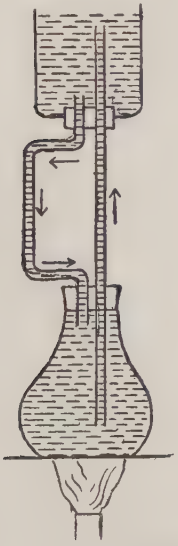


2. Lift Pump

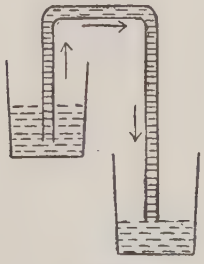


4. A claw hammer : a Lever of the First Class

(Label the fulcrum, force, and resistance)



3. Convection Currents in a Liquid



5. A Siphon

General Science Examination

New 6

Part A.

1. T. F. The higher the altitude the lower the reading of the mercurial barometer.
2. T. F. Convection current is a special type of electric current.
3. T. F. Hard water is water containing some impurity like germs.
4. T. F. Salt sprinkled on ice on a sidewalk will melt the ice at temperature below zero degrees Centigrade.
5. T. F. The earth is nearer to the sun than both Mars and Venus.
6. T. F. Air is composed of a mixture of Oxygen—21%, Hydrogen—78%, Argon—1%, Carbon dioxide—0.04% and traces of other substances.
7. T. F. Like poles of a magnet attract, unlike poles repel each other.
8. T. F. A body weighs less in air than it would weigh in a vacuum.
9. T. F. The stars are larger than the moon.
10. T. F. The warmer the air the more water vapor it can hold.

Part B.

1. How many degrees are there between the freezing and boiling points on a Fahrenheit thermometer? .....
2. On a certain day the air had 3/4 enough moisture in it to make it saturated. What was the relative humidity? ....
3. What is the weight of air resting on an object 4 by 9 inches? .....
4. How much potential energy has a 15 lb. weight raised 10 ft.? .....
5. What is the efficiency of a steam engine if it transforms 5 ft. lbs. of energy out of every 100 ft. lbs. of potential energy in coal into mechanical energy? .....
6. How many ft. lbs. of work can a 5 Horse-Power engine do in a minute? .....
7. How much does a toy boat having a displacement of 100 cubic centimeters of water weigh? .....

8. A cube made of wood, 10 inches in all dimensions sinks to a depth of 8 inches in water. What is its density? .....
9. A lever of the first class is 10 feet long. A weight of 8 lbs. is placed at one end, 6 feet from the fulcrum. How many pounds must be at the other end in order to balance it? ...
10. If you are pulling with a force equal to 125 lbs. on the end of a rope of a set of pulleys containing 6 strands of rope, how heavy a weight can you raise? (Neglect friction) ....

Part C.

1. The smallest possible particle of a substance (water, manganese dioxide, sodium chloride, etc.) is—an atom, 1/1,000 of an oz., a molecule, 1/1,000 of a gram.
2. Lime water is turned milky by—Nitrogen, Carbon dioxide, Oxygen, Hydrogen.
3. The sun is a—star, planet, satellite, constellation.
4. The best conductor of electricity is—glass, rubber, copper, silver.
5. A high reading of the barometer means—fair weather, rainy weather, a cold wave, a hot wave.
6. The passage of the moon between the sun and the earth causes —eclipse of the moon, eclipse of the earth, eclipse of the sun, new moon.
7. The slide valve is found in the—steam engine, lift pump, ice machine, hydraulic press.
8. The filament in the best modern incandescent lamp is made of—copper, tungsten, carbon, steel.
9. The density of water is greatest at a temperature of—100 degrees C., 0 degrees C., 20 degrees C., 4 degrees C.
10. Which of the following parts of a dry cell forms the negative pole? Carbon rod, zinc cup, sal ammoniac, zinc chloride.

Part D.

In the use of the ordinary wire telephone the sound produced at the transmitting end is converted into a varying electric current which flows along the wires, this current being changed back again into sound in the telephone receiver at the other end. Radio telephony is similar except that there are no connecting wires. There must be arrangements at the transmitting end for converting

the speech into an electric wave and at the receiving end arrangements for converting the received electric wave into sound. The great difference between the two is that the electric action has been carried by means of electric waves passing through the air instead of by means of electric current passing along a wire. (Lefax Radio Handbook, Chapter one, p. 2.)

1. By means of a radio transmitter we can send the sound waves of our voice through the air to all parts of the world.
2. In radio telephony at the transmitting end electric waves are converted into sound waves, and at the receiving end the sound waves are converted back again into electric waves.
3. In radio telephony at the transmitting end the sound waves of speech are converted into an electric wave, and at the receiving end the electric wave is converted back again into sound.
4. The principle of radio telephony and the ordinary wire telephone is the same, except that in the former case there are no connecting wires.

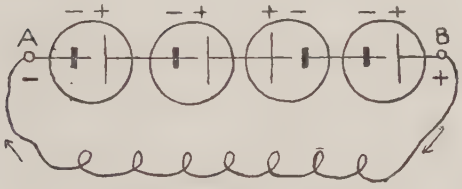
Part E.

1. When you get into a rowboat how much more water must the rowboat displace?
   a. About 100 lbs. more water.
   b. An amount of water equal to your weight.
   c. It does not displace any more water.
   d. Twice as much water.
2. What is the difference between the light produced in a kerosene lamp and in an incandescent lamp?
   a. The principle is the same, but the incandescent lamp gives more illumination.
   b. The filament of an incandescent lamp burns in a vacuum, and the kerosene of the lamp burns in air.
   c. Oxidation in the kerosene lamp, resistance of filament to the passage of electric current in the incandescent lamp.
   d. The incandescent lamp depends upon an electric current and the kerosene lamp does not.
3. In making a cement sidewalk why is the cement cut into squares?

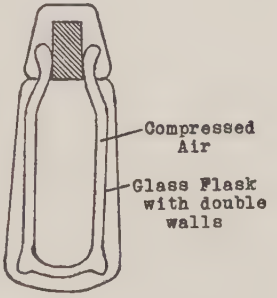
a. To allow for expansion during warm weather.
b. The design improves its appearance.
c. Less cement is required and it is therefore cheaper.
d. To allow the cement to expand during cold weather.

4. Why have cooking utensils wooden handles?
   a. Iron is a poorer conductor of heat than wood.
   b. Wooden handles are cheaper than metallic handles.
   c. Iron feels colder to the hand than wood.
   d. Wood is a poor conductor of heat.
5. To obtain a supply of carbon dioxide in the laboratory we used—
   a. Potassium chlorate and manganese dioxide.
   b. Calcium carbonate and hydrochloric acid.
   c. Ammonium chloride and sodium nitrite.
   d. Commercial zinc and dilute sulphuric acid.

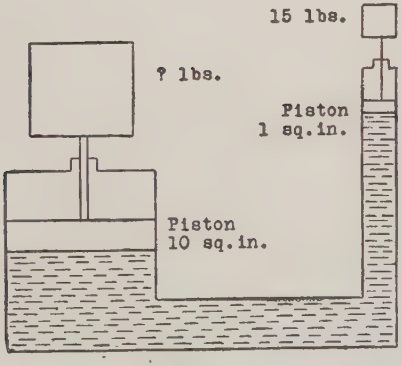
Part F.



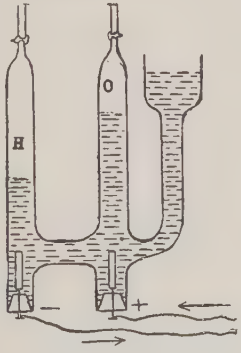
1. Cells Arranged in Series



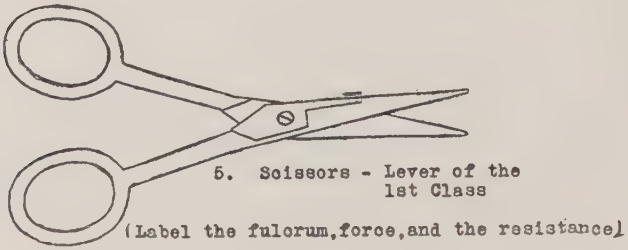
2. Thermos Bottle



3. Hydraulic Press



4. Electrolysis of Water



INSTRUCTIONS FOR GIVING GENERAL SCIENCE EXAMINATIONS

General Directions

"We are going to have a new kind of examination in General Science. I do not expect you to be able to answer all the questions, but of course, you are to try your best. It is very important that you follow the directions carefully, as nothing will be repeated. Do exactly what you are told to do. Do not look to see what anyone else is doing. I wish to find out what you can do. Ask no questions. Do not begin work until the signal 'Go' is given and stop work immediately when the signal 'Stop all work' is given. We will all begin and stop each part of this test at the same time. All work is to be done in pencil. Turn over each sheet on the blank side as soon as you have finished any part of this examination."

New 1

Part A. True and False Statements.

"Read the ten statements in Part A. Mark each one at the left of its number with a 'T' if you think it is true, or with an 'F' if you think it is false. Each statement marked correctly counts in your favor; each incorrectly marked statement counts as a penalty against you, and is subtracted from your score. Omitted statements count neither for nor without you. First go through the list quickly and mark all that you are sure you know, then go back and study out the harder ones. Do not guess. The chances are against you on guessing. Ready—Go. (Time —4 minutes.) Stop all work. Pencils up."

Part B. Best Answer. Recognition of Words and Phrases.

"There are five incomplete statements in Part B. Underline the word or phrase following each statement that will make the best answer. You will not be penalized for errors in this part of the examination so that it pays to take a chance even where you are not quite sure. Ready—go. (Time—3 minutes.) Stop all work. Pencils up."

Part C. Best Answer. Recognition of Statements.

"There are five incomplete statements in Part C. Place a check mark in front of the sentence that will make the best answer. As in Part B you will not be penalized for errors, so it pays to take a chance even where you are not quite sure. Please note that number 5 is continued on the second sheet. Ready—go. (Time —5 minutes.) Stop all work. Pencils up."

Part D. Comprehension of New Scientific Material.

"There are four paragraphs in Part D copied from text books in General Science. Read each paragraph carefully. Then read the statements below and put a check mark in front of each statement which is true and contains an idea that is in the paragraph above or can be derived from it. The paragraphs and statements may be re-read as often as it is necessary. There may be more than one correct statement to be checked following a paragraph. Ready—go. (Time—6 minutes.) Stop all work. Pencils up."

Part E. Logical Arrangement and Problem.

"Part E consists of two questions. In the first question arrange the parts of an experiment in the proper order by a number indicating the correct order placed after each. Do the problem in question 2 on the blank side of sheet one which you have turned upside down. Ready—go. (Time—4 minutes.) Stop all work. Pencils up."

Part F. Diagrams.

"There are three possibilities you are to think of in the case of the four diagrams on this sheet. The diagram may be correct. In that case you are to place an O. K. on it. It may have a part missing. In that case you are to add the missing part. Or it may have a part put in wrong. In that case you are to make the

proper correction. Ready—go. (Time 4 minutes.) Stop all work. Pencils up."

New 2

Part A. True and False Statements.

"Read the ten statements in Part A and mark each one alongside of its number with a T if you think it is true, or with a F if you think it is false. Each statement marked correctly counts in your favor, each incorrectly marked statement counts as a penalty and is subtracted from your score. Omitted statements count neither for nor against you. First go through the list quickly and mark all that you are sure you know, then go back and study out the harder ones. Do not guess. The chances are against you on guessing. Ready—go. (Time—4 minutes). Stop all work. Pencils up."

Part B. Problems.

"Part B consists of five problems. Fill in the answers on the dotted lines following them. You may use the blank side of sheet 2 for any rough work. If you do not know how to do any of them go ahead to the next ones. If you finish before time is up, go back and make sure your answers are correct. Ready—go. (Time—6 minutes). Stop all work. Pencils up."

Part C. Best Answer. Recognition of Words and Phrases.

"There are 10 incomplete statements in Part C. Underline the word or phrase following each statement that will make the best answer. You will not be penalized for errors in this part of the examination so that it pays to take a chance even where you are not quite sure. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Part D. Best Answer. Recognition of Statements.

"There are five questions asked in Part D. Place a check mark in front of the statement that will make the best answer. As in Part C you will not be penalized for errors, so that it pays to take a chance even where you are not quite sure. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Part E. Comprehensions of New Scientific Material.

"Part E consists of a paragraph copied from a textbook in

General Science. Read the paragraph carefully. Then read the statements below and put a check mark in front of each statement which is true and contains an idea that is in the paragraph above or can be derived from it. The paragraph and statements may be re-read as often as it is necessary. There may be more than one correct statement to be checked. Ready—go. (Time—4 minutes). Stop all work. Pencils up."

Part F. Diagrams.

"There are three possibilities you are to think of in the case of the five diagrams on the sheet. The diagram may be correct. In that case you are to place an O. K. on it. It may have a part missing. In that case you are to add the missing part. Or it may have a part put in wrong. In that case you are to make the proper correction. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

New 3

Part A. True and False Statements.

"Read the ten statements in Part A. In each case make a circle around the capital letter T if you think it is true, or around the capital letter F if you think it is false. Each statement marked correctly counts in your favor, each incorrectly marked statement counts as a penalty against you, and is subtracted from your score. Omitted statements count neither for nor against you. First go through the list quickly and mark all that you are sure you know. Then go back and study out the harder ones. Do not guess. The chances are against you on guessing. Ready—go. (Time—4 minutes). Stop all work. Pencils up."

Part B. Problems.

"Fill in the answers to the six problems in Part B on the dotted lines. You may use the blank side of sheet 2 for any rough work. If you do not know how to do any of them go ahead to the next ones. If you finish before time is up, go back and make sure your answers are correct. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Part C. Best Answer. Recognition of Words and Phrases.

"There are eight incomplete statements in Part C. Read all

the words or phrases following each statement, then underline the word or phrase that would make the truest statement. You will not be penalized for errors so that it pays to guess even where you are not quite sure. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Part D. Best Answer. Recognition of Statements.

"There are six incomplete statements in Part D. Read all the four choices following each incomplete statement before you choose the one which you consider to be correct. Then place a check mark on the dotted line in front of the best answer. In each case you will not be penalized for errors so that it pays to guess even where you are not quite sure. Please notice that Part D is continued on the second sheet. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Part E. Comprehension of New Scientific Material.

"Part E consists of two paragraphs copied from a textbook in General Science. Read each paragraph carefully. Then read all the statements following the paragraph and place a check mark on the dotted line in front of each statement which is true and contains an idea that is in the paragraph above or can be derived from it. The paragraph and statements may be re-read as often as it is necessary. There may be more than one correct statement to be checked following a paragraph. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Part F. Diagrams.

"Part F consists of five diagrams. There are three possibilities you are to think of in the case of each diagram. The diagram may be correct. In that case you are to place an O. K. on it. It may have a part missing. In that case you are to add the missing part. Or it may have a part put in wrong. In that case you are to make the proper correction. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

New 4

Part A. True and False Statements.

"Read the ten statements in Part A. In each case make a circle around the capital letter T if you think it is true, or around

the capital letter F if you think it is false. Each statement marked correctly counts in your favor, each incorrectly marked statement counts as a penalty against you, and is subtracted from your score. Omitted statements count neither for nor against you. First go through the list quickly and mark all that you are sure you know. Then go back and study out the harder ones. Do not guess. The chances are against you on guessing. Ready—go. (Time—3 minutes.) Stop all work. Pencils up."

Part B. Problems.

"Fill in the answers to the five problems in Part B on the dotted lines. You may use the blank side of sheet 2 for any rough work. If you do not know how to do any of them go ahead to the next ones. If you finish before time is up, go back and make sure your answers are correct. Ready—go. (Time—6 minutes). Stop all work. Pencils up."

Part C. Best Answer. Recognition of Words and Phrases.

"There are five incomplete statements in Part C. Read all the words or phrases following each statement, then underline the word or phrase that would make the truest statement. You will not be penalized for errors in this part of the examination so that it pays to guess even where you are not quite sure. Ready—go. (Time—2 minutes). Stop all work. Pencils up."

Part D. Comprehension of New Scientific Material.

"Part D consists of an extract from a magazine article. Read the paragraph carefully. Then read all the statements following the paragraph. Place a circle around the number in front of each statement which is true and contains an idea that is in the paragraph above or can be derived from it. The paragraph and statements may be re-read as often as it is necessary. There may be more than one correct statement to be checked. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part E. Best Answer. Recognition of Statements.

"There are eight incomplete statements in Part E. Read all the four choices following each incomplete statement before you choose the one which you consider to be correct. Then place a check mark on the dotted line in front of the best answer. In

each case you will not be penalized for errors so that it pays to guess even where you are not quite sure. Ready—go. (Time—4 minutes). Stop all work. Pencils up."

Part F. Diagrams.

"Part F consists of four diagrams. There are three possibilities you are to think of in the case of each diagram. The diagram may be correct. In that case you are to place an O. K. on it. It may have a part missing. In that case you are to add the missing part. Or it may have a part put in wrong. In that case you are to make the proper correction. Ready—go. (Time—4 minutes). Stop all work. Pencils up."

New 5

Part A. True and False Statements

"Read the ten statements in Part A. In each case make a circle around the capital letter T if you think it is true, or around the capital letter F if you think it is false. Each statement marked correctly counts in your favor, each incorrectly marked statement counts as a penalty against you, and is subtracted from your score. Omitted statements count neither for nor against you. First go through the list quickly and mark all that you are sure you know. Then go back and study out the harder ones. Do not guess. The chances are against you on guessing. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part B. Problems.

"Fill in the answers to the ten problems in Part B on the dotted lines. You may use the blank side of sheet 2 for any rough work. If you do not know how to do any of them go ahead to the next ones. If you finish before time is up, go back and make sure your answers are correct. Ready—go. (Time—10 minutes). Stop all work. Pencils up."

Part C. Best Answer. Recognition of Words and Phrases.

"There are eight incomplete statements in Part C. Read all the four words or phrases following each statement, then underline the work or phrase that would make the truest statement. You will not be penalized for errors so that it pays to guess even where

you are not quite sure. Ready—go. (Time—3 minutes.) Stop all work. Pencils up."

Part D. Comprehension of New Scientific Material.

"Part D consists of an extract from a magazine article by Dr. Steinmetz, the famous electrical expert. Read the paragraph carefully and then read all the four statements following the paragraph. Place a check mark on the dotted line in front of the statement which is true and contains an idea that is in the paragraph above or can be derived from it. The paragraph and statements may be re-read as often as it is necessary. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part E. Best Answer. Recognition of Statements.

"There are four incomplete Statements in Part E. Read all the four choices following each incomplete statement before you choose the one which you consider to be correct. Then place a check mark on the dotted line in front of the best answer. In each case you will not be penalized for errors so that it pays to guess even where you are not quite sure. Ready—go. (Time—4 minutes). Stop all work. Pencils up."

Part F. Diagrams.

"Part F consists of five diagrams. There are three possibilities you are to think of in the case of each diagram. The diagram may be correct. In that case you are to place an O. K. on it. It may have a part missing. In that case you are to add the missing part. Or it may have a part put in wrong. In that case you are to make the proper correction. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

New 6

Part A. True and False Statements.

"Read the ten statements in Part A. In each case make a circle around the capital letter T if you think it is true, or around the capital letter F if you think it is false. Each statement marked correctly counts in your favor, each incorrectly marked statement counts as a penalty against you, and is subtracted from your score. Omitted statements count neither for nor

against you. First go through the list quickly and mark all that you are sure you know. Then go back and study out the harder ones. Do not guess. The chances are against you on guessing. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part B. Problems.

"Fill in the answers to the ten problems in Part B on the dotted lines. You may use the blank side of sheet 2 for any rough work. If you do not know how to do any of them go ahead to the next ones. If you finish before time is up, go back and make sure your answers are correct. Ready—go. (Time—10 minutes). Stop all work. Pencils up."

Part C. Best Answer. Recognition of Words and Phrases.

"There are ten incomplete statements in Part C. Read all the four words or phrases following each statement, then underline the word or phrase that would make the truest statement. You will not be penalized for errors so that it pays to guess even where you are not quite sure. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part D. Comprehension of New Scientific Material.

"Part D consists of an extract from a book on Radio. Read the paragraph carefully and then read all the four statements following the paragraph. Place a check mark on the dotted line in front of the statement which is true and contains an idea that is in the paragraph above or can be derived from it. The paragraph and the statements may be re-read as often as it is necessary. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part E. Best Answer. Recognition of Statements.

"There are five incomplete statements in Part E. Read all the four choices following each incomplete statement before you choose the one which you consider to be correct. Then place a check mark on the dotted line in front of the best answer. In each case you will not be penalized for errors so that it pays to guess even where you are not quite sure. Ready—go. (Time—3 minutes). Stop all work. Pencils up."

Part F. Diagrams.

"Part F consists of five diagrams. There are three possibilities

you are to think of in the case of each diagram. The diagram may be correct. In that case you are to place an O. K. on it. It may have a part missing. In that case you are to add the missing part. Or it may have a part put in wrong. In that case you are to make the proper correction. Ready—go. (Time—5 minutes). Stop all work. Pencils up."

Summary

1. An experiment extending over two consecutive terms was conducted with two separate groups of pupils, a total of 291 boys, taking General Science.

2. The Terman and the Army Alpha Group Intelligence were given in order to determine the general learning capacity of the pupils.

3. This was followed by a parallel series of three conventional and three new types of tests in General Science, both covering practically identical content and progressively cumulative in nature, for the purpose of ascertaining their relative advantages and disadvantages as measures of achievement.

4. The construction, administration and scoring of the conventional tests were planned so as to make them as scientific and reliable as possible.

5. The new tests were modeled after the best of our group tests in general intelligence, standardized tests and scales and the new type of examination given to students at Columbia University.

CHAPTER V

A CONSIDERATION OF THE CORRELATION BETWEEN ATTAINMENT IN SUBJECT MATTER AND GENERAL MENTAL CAPACITY

In the technical sense it is hardly likely that a majority of our leading psychologists will agree upon a definition of general intelligence. However, there is a remarkable unanimity of opinion with respect to a working definition from an educational point of view as shown by the extracts which follow.

1. B. R. Buckingham: "Whatever our views may be in regard to the nature of intelligence in the abstract, we are justified, from an educational point of view, in regarding it as ability to learn, and as measured to the extent to which learning has taken place or may take place."[1]

2. S. S. Colvin: "There is no reasonable doubt that the intelligence tests do indicate to a fair degree native ability to learn . . . They are valuable in indicating the probable success of pupils in school."[2]

3. M. E. Haggerty: "However we may technically define intelligence, what we mean by it here is that capacity which enables a pupil to profit by the work of a good school, to recognize the meaning of words and sentences, to remember important facts observed and learned, to discriminate essential from unessential materials, and to infer correct conclusions from presented data."[3]

4. H. W. Holmes: "It may be granted that tests of intelligence distinguish with reasonable accuracy between children

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[1] Buckingham, B. R.: "Intelligence and its Measurement: A Symposium," The Journal of Educational Psychology, 12: 271-5, May, 1921, p. 273.

[2] Colvin, S. S.: "The Present Status of Mental Testing," Educational Review, 64: 320-37, November, 1922, p. 336.

[3] Haggerty, M. E.: Manual of Directions for Achievement Examination in Reading: Sigma 1, and Intelligence Examinations: Delta 1 and Delta 2, p. 6.

of superior intellectual ability and their duller companions . . . They do measure his ablity to learn in school."[4]

5. W. S. Monroe: "For practical school purposes general intelligence may be thought of as the measurement of the pupil's general capacity to do the work of the school."[5]

6. R. Pintner: "A child of inferior mentality cannot be expected to accomplish educationally as much as a child of superior mentality . . . The raw material with which the teacher has to work is the native ability of the child, and this determines the degree of modifiability or the rate of learning. Good raw material is easily modifiable and the rate of learning is rapid. Poor raw material is hard to modify and the rate of learning is slow . . . The basic differences in the mental ability of the pupils, which in all probability are the chief reasons for the differences in educational attainment, are seldom mentioned or when mentioned, seem to be considered of secondary importance."[6]

7. W. H. Pyle: "We have found reason to believe that there is a general factor which we call general learning capacity. . . . The general learning factor and the general intellectual factor are probably the same."[7]

8. L. M. Terman: "General intelligence is the thing that determines what progress a child in a particular school subject should make."[8]

9. E. L. Thorndike: "Realizing that definitions and distinctions are pragmatic, we may then define intellect as the power of good responses from the point of view of truth or fact, and may separate it according as the situation is taken in gross or abstractly and also according as it is experienced directly or thought of. The power of good responses to abstract qualities and relations rather than gross total facts and to ideas rather than direct experiences may be called the more intellectual variety of intellect . . .

The value of a test score is its value in prophesying how

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[4] Holmes, H. W.: "The General Philosophy of Grading and Promotion in Relation to Intelligence Testing," School and Society, 15: 457-61, April 29, 1922, p. 461.

[5] Monroe, W. S.: An Introduction to the Theory of Educational Measurements, p. 39.

[6] Pintner, R.: The Twenty-First Yearbook, Intelligence Tests and Their Use, pp. 162-3.

[7] Pyle, W. H.: The Psychology of Learning, p. 171.

[8] Terman, L. M.: Intelligence Tests and School Reorganization, p. 91.

well a person will do in other intellectual tasks . . . If the boy has had ordinary American opportunities, this score will prophesy rather accurately how well he will respond to intellectual demands in the case of 'book-learning' at the time and for some years thereafter, and very possibly for all his life."[9]

10. M. R. Trabue: "The pupils who make high scores on the intelligence tests are the ones who enjoy and can easily master the books and abstract ideas offered in the schools . . . Studies of their correlations have proved that they predict success in school more accurately than it is predicted by the judgment of the average teacher."[10]

11. L. Witmer: "Intelligence is the ability to solve a new problem . . . Intelligence is a congenital though not inherited endowment, and the amount of it cannot be increased by training."[11]

Limitations of Ratings in General Intelligence

The limitations of intelligence tests must be kept in mind before we are justified in making any far-reaching inferences on the basis of their results. The following are significant:

1. Time allowances.—It is often claimed that the time limits on general intelligence tests are unfair to the slow, accurate thinker. An experiment conducted with the Army Alpha test on 510 men at Camps Beauregard and MacArthur demonstrated that this is not true. These men were given the Army Alpha test with the time allotments for each part doubled and the total score compared with scores previously made under standard time conditions. The correlation of single-time total score with double-time total score was found to be 0.965 or practically equivalent to unity.[12]

2. Ability in English.—Colvin[13] believes that since our

[9] Thorndike, E. L.: "Intelligence and Its Measurement: A Symposium." The Journal of Educational Psychology, 12: 124-7, March, 1921, pp. 124-5.

[10] Trabue, M. R., "Some Pitfalls in the Administrative Use of Intelligence Tests," Journal of Educational Research, 6: 1-11, June, 1922, pp. 3 and 5.

[11] Witmer, L.: "What is Intelligence and Who Has It?", in Ninth Annual Schoolmen's Week Proceedings, p. 45.

[12] Yerkes, R. M. (Editor): Psychological Examining in the United States Army, National Academy of Sciences, Volume XV, pp. 415-6.

[13] Colvin, S. S. and Allen, R. D.: "Mental Tests and Linguistic Ability," The Journal of Educational Psychology, 14: 1-20, January, 1923.

thinking is conditioned by our linguistic knowledge and ability, even the so-called non-verbal tests are not strictly speaking non-verbal in the broad sense and, that it is impossible to frame intelligence tests that do not involve such abilities. In regard to judgments based on such tests, he says: "It seems probable that all mental tests that are largely linguistic will be unfair to those persons whose training in English either at home or in the schools has been inferior. It is only when individuals tested have had common opportunities to learn the vernacular that real differences in intelligence can be surely inferred from the scores secured."[14]

3. Social heredity.—Inglis[15] maintains that "individual differences among secondary-school pupils due to biological heredity are relatively unimportant, but that individual differences due to social heredity are great and important." Madsen[16] found that the racial and social origin of groups of high-school students markedly affected their ratings in general intelligence.

4. Imperfect correlations between different group intelligence tests.—The different group intelligence tests do not all measure exactly the same aspects of mentality so that a perfect correlation could not be expected even if these tests were free from defects. There is a high correlation between tests that have received recognition in this field but the correlation is by no means a close approach to unity. The Chicago, Otis and Terman Group tests administered to the ninth grade of the University of Chicago High School were found to have an average inter-test correlation of .77.[17] The Otis Intelligence Test and the Illinois Examination were given to 120 pupils of the Junior High School of the Chicago Normal School and the coefficient of correlation by the rank difference method was found to be .642.[18] King[19] in a com-

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[14] Colvin, S. S.: The Twenty-First Yearbook, Intelligence Tests and Their Use, p. 23.

[15] Inglis, A.: Principles of Secondary Education, p. 97.

[16] Madsen, I. N.: "Interpreting Achievement in School in Terms of Intelligence." The American School Board Journal, 63: 41, 111, November, 1921, p. 41.

[17] Breed, F. S.: "Shall we Classify Pupils by Intelligence Tests?" School and Society, 15: 406-409, April 15, 1922, p. 408.

[18] Geyer, D. L.: "The Reliability of Rankings by Group Intelligence Tests," The Journal of Educational Psychology, 13: 43-49, January, 1922, p. 43.

[19] King, Leroy, A.: "A Comparative Study of Group Intelligence Tests," in Eighth Annual Schoolmen's Week Proceedings, pp. 78-92.

parative study of the Dearborn, Haggerty, National and Terman Group Intelligence Tests found an inter-test correlation ranging from .59 to .71 between the scores of 184 seventh grade pupils.

The average and median scores in both the Terman and Army Alpha Group Intelligence Tests for High School Freshmen and the correlations between the scores were unusually high in the experiment conducted by the writer as shown by the following table:

TABLE 6

INTELLIGENCE TESTS IN STUDY

	Number of cases	*Correlations between Terman and Army Alpha*	*Average score Terman*	*Median score Terman*	*Average score Army Alpha*	*Median score Army Alpha*
First Series.....	139	.817 ± .0186	120	118	107	102.5
Second Series...	133	.847 ± .0161	142	144.5	106	106.5
Median Score for H. S. Freshmen.....				105[20]		97[21]

5. Validity of Results.—Terman sums up the status of mental testing in a masterly way as follows:

"Mental measurements are not and never will be made with the exactness which is possible in the physical sciences. 'Accidental' and imponderable factors are always present to invalidate the result in some degree. This would be true even if the measuring scale itself were perfect, for the child himself is a more or less variable factor. His performance in the tests may be influenced by conditions of health, the previous night's sleep, fatigue, timidity, anxiety, grief . . . and other special conditions. When the different tests of the same individual are made by different examiners, we have the additional disturbing influence of the personal equation in giving and scoring the tests.

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[20] Terman, L. M.: Manual of Directions, Terman Group Test of Mental Ability, p. 9.

[21] De Voss, J. C.: Manual of Instructions, For Use with the Army Alpha Intelligence Tests, p. 23.

Some persons have argued that such accidental influences largely invalidate the results of mental testing. Such persons take it for granted that an average child may test like a dullard if he is fatigued or sleepy, and that similar factors beyond our control may reduce the performance of a genius to the level of mediocrity. The question is one of fact. The results of re-tests show that, while theoretically all these influences may be present in some degree, their combined influence is in most cases small."[22]

However, in spite of the disagreement of psychologists as to what is meant by general intelligence, and the limitations of general intelligence ratings that were pointed out, from a practical point of view so far as their use in school is concerned, they all agree essentially on the validity of such tests as the best available measures of educability, and of their diagnostic value in predicting accomplishment in school subjects. Therefore, we will not be fundamentally in error if we use the term general intelligence as if it were practically identical with native learning ability.

Furthermore, we are justified in presupposing, on the basis of previous studies of the distribution of mental abilities by Thorndike and other psychologists, that abilities in General Science as well as in other school subjects are composites which would be distributed in conformity with the normal probability curve if the scores in a sufficient number of cases could be tabulated. It was not possible in this study to include more than a total of 208 pupils who took all the tests given, so that a direct investigation of the relative extent to which the new and conventional tests in General Science approached the limits set to achievement in that subject by specific capacity could not be made. Therefore, the practical expedient was adopted of studying the relative correlations of the new tests and of the conventional tests with the Terman and Army Alpha Group Intelligence Tests, since these tests have been given to thousands of individuals and their distribution does conform to the Gaussian curve. Thus an indirect conception of the absolute distribution of the scores in the new and ordinary tests in General Science may be obtained.

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[22] Terman, L. M.: The Intelligence of School Children, pp. 137-8.

A search of educational literature revealed the fact that very little has been done in this particular field. Studies have been made of the correlations between general intelligence and final grades but very few of specific performances in written tests. Some investigations have been made of correlations between general intelligence and standardized tests, especially in the elementary school and invariably found to be high, but since the new tests are not standardized tests the results do not have a direct bearing on the problem.

Several interesting experiments are worthy of brief mention here. Breed and Breslich[23] found that the correlation of ordinary school tests in algebra and the Hotz test with a composite of the scores in the Otis, Terman and Chicago Group Intelligence Tests was .31 and .56 respectively. Homer Davis[24] gave the Alpha Intelligence Tests to a history class composed of 80 men and 14 women and also nine examinations in history during the first quarter of the term and the correlation between the average of these tests with the Alpha was found to be .32, a rather low correlation and almost the same as that found by Breed and Breslich between their ordinary test in algebra and general intelligence.

Franzen[25] gave the Stanford-Binet Tests to children in the elementary grades above grade 3 at Garden City, New York between November 1918 and June 1920 in order to classify them by homogeneous groups on the basis of their intellectual ability. Then under his direction the teachers gave them the Woody-McCall Mixed Fundamentals in Arithmetic, the Thorndike Reading Scale, Alpha 2, the Thorndike Visual Vocabulary Scale, A-2, the Kelley-Trabue Completion Exercises in Language in order to test their accomplishment on the basis of their mental capacity.

The total number of pupils, about 200, were re-graded and divided as far as possible into six groups, corresponding to grades 3, 4, 5, 6, 7 and 8 in subject matter represented by the achievement tests given, and within these six groups a further classifica-

[23] Breed, F. S. and Breslich, E. R.: "Intelligence Tests and the Classification of Pupils," The School Review, 30: 210-26, March, 1922, p. 219.

[24] Davis, H.: "Army Alpha and Students' Grades, Illustrating the Value of the Regression Equation," School and Society, 14: 223-7, September, 1921, p. 223.

[25] Franzen, R.: The Accomplishment Ratio. Teachers College, Columbia University Contributions to Education, No. 125, pp. 11-14, 24.

tion was made whenever opportunity offered itself on the basis of their intelligence scores. They were, therefore, grouped for instruction according to their general mental abilities and specific abilities in various academic fields, and pushed to the maximum of their capacities for a period of two years.

He found the following intercorrelation of all quotients for all periods of the 48 children who took all tests:

	IQ	*Arithmetic Quotient*	*Vocabulary Quotient*	*Reading Quotient*
Arithmetic Quotient. .	.733	....	....	....
Vocabulary Quotient.	.837	.628	....	....
Reading Quotient. . . .	.758	.694	.734	....
Completion Quotient.	.821	.770	.825	.801

Therefore, he concluded that when children are grouped according to native abilities and then pushed to the limits of their capacities, the correlation between their accomplishment in school measured objectively and their intelligence almost reaches unity. Franzen, however, in making his inferences apparently slighted certain difficulties. We still do not know just what is meant by general intelligence and its exact significance to the teacher as an index of the character of the raw material to be changed in the educational process. Moreover, his study was limited in scope in two other respects. The total number of children who took all of the tests was only 48 and it was restricted to arithmetic, vocabulary and reading tests in the elementary grades.

The investigation by Wood[26] at Columbia presents several points of agreement with the experiment as planned and executed by the author. He took the records of three groups of 500 freshmen, or about 1500 in all, who were admitted to Columbia University during the past three years and made a comparative study of the conventional and new types of tests on the basis of general intelligence ratings. The scores in the Thorndike College Entrance Intelligence Examination for High School Graduates were taken as a measure of their mental ability. The correlations between the scores in the usual essay style of final examination in Contem-

[26] Letter from Mr. Wood, giving information based on his forthcoming book: Wood, B. D.: Measurement in Higher Education.

porary History and also in other subjects, consisting of from 6 to 10 questions of the discussion form, was between 0.40 and 0.50 and between the scores in the New type of examination in Contemporary Civilization was about 0.60 (Pearson Product-Moment Method).

Correlations Obtained in the Experiment with General Science Classes

The Tables of Correlations of the new and conventional tests in General Science with the Terman and Army Alpha Group Intelligence Tests used in the experiment, computed by the Pearson Product-Moment Method, and the accompaning graphs which follow are largely self-explanatory.

Table 7

Correlations of the Scores of Ninth-Grade Students in General Science Tests with Group Intelligence Tests

Series 1 (January to June 1922)

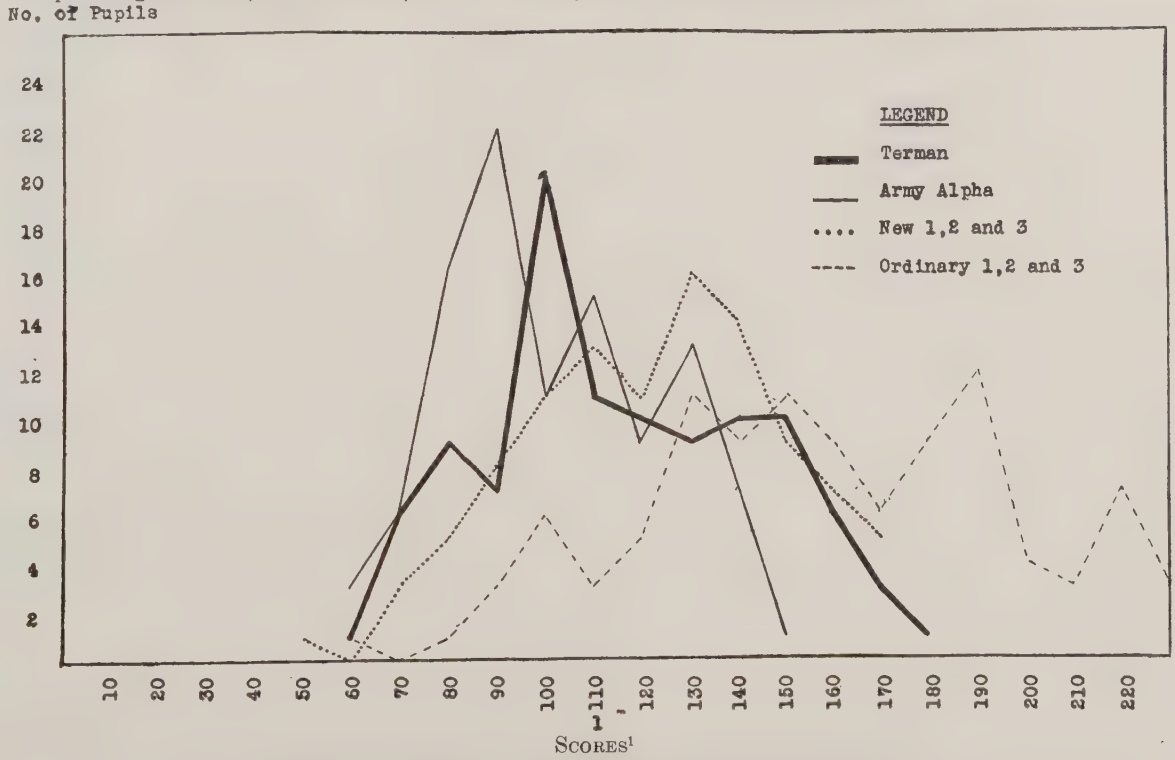
	No. of Cases	*Terman*	*Army Alpha*	*Terman and Army Alpha*
New 1	140	.476 ± .0438		
	130		.446 ± .047	
New 2	131	.52 ± .0429		
	127		.375 ± .051	
New 3	115	.608 ± .039	.37 ± .054	
New 1, 2, and 3	103	.618 ± .0408	.48 ± .051	.59 ± .043
Ordinary 1	140	.136 ± .055		
	130		.18 ± .057	
Ordinary 2	131	.328 ± .0429		
	127		.248 ± .056	
Ordinary 3	115	.41 ± .042	.36 ± .056	
Ordinary 1, 2 and 3	103	.36 ± .0578	.34 ± .0587	.37 ± .057

TABLE 8

CORRELATIONS OF THE SCORES OF NINTH-GRADE STUDENTS IN GENERAL SCIENCE TESTS WITH GROUP INTELLIGENCE TESTS
Series 2 (September 1922 to January 1923)

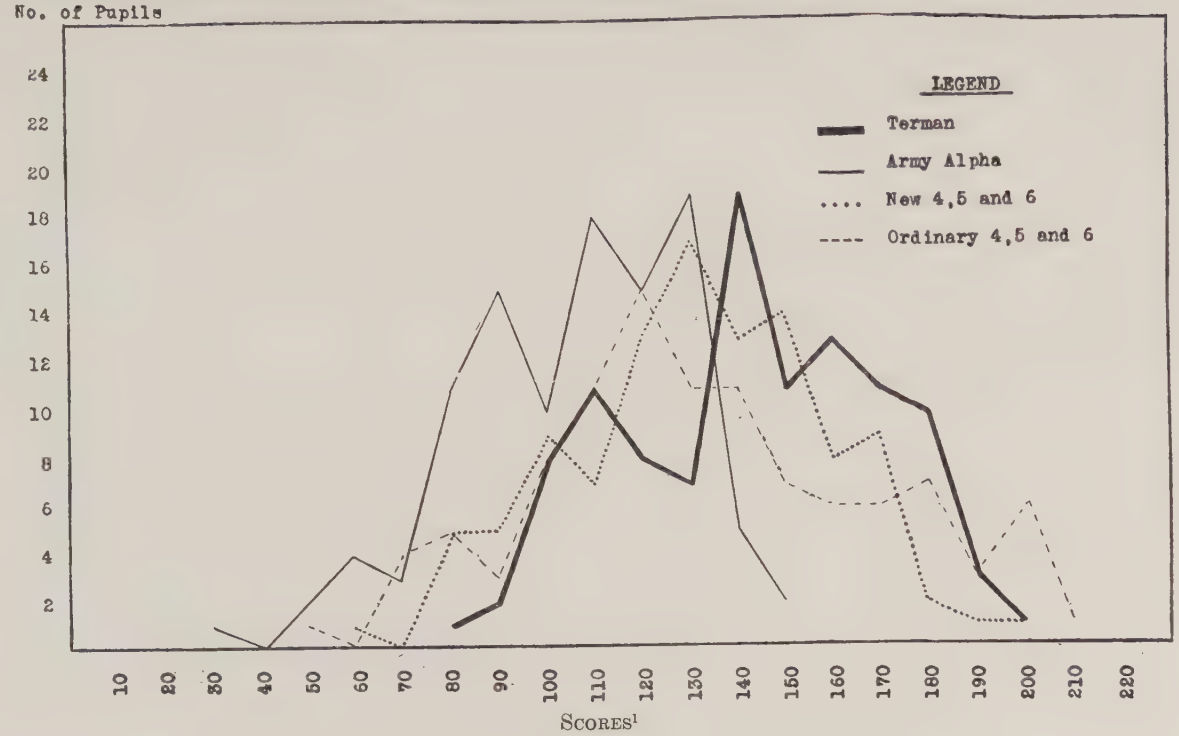
	No. of Cases	*Terman*	*Army Alpha*	*Terman and Army Alpha*
New 4	129	.475 ± .0458		
	128		.499 ± .0445	
New 5	125	.659 ± .0341	.564 ± .041	
New 6	107	.58 ± .0424	.548 ± .045	
New 4, 5, and 6	105	.64 ± .0384	.577 ± .0438	.63 ± .039
Ordinary 4	129	.572 ± .0397		
	128		.49 ± .0451	
Ordinary 5	125	.55 ± .0417	.46 ± .047	
Ordinary 6	107	.539 ± .0458	.46 ± .0505	
Ordinary 4, 5, and 6	105	.648 ± .0377	.508 ± .0485	.618 ± .0406

DIAGRAM 1. Comparative Frequency Distributions of 103 Ninth-Grade Students in the Terman and Army Alpha Group Intelligence Tests, the New Tests, and the Ordinary Tests in General Science, Series 1.



[1] The total point score in the general science tests was multiplied by 2.

DIAGRAM 2. Comparative Frequency Distributions of 105 Ninth-Grade Students in the Terman and Army Alpha Group Intelligence Tests, the New Tests, and the Ordinary Tests in General Science. Series 2.



[1] The total point score in the general science tests was multiplied by 2.

Interpretation of the Correlations

The correlations of the rating in the new tests with those in general intelligence were uniformly high, ranging from .37 to .65 in the different forms. On the other hand, the correlations of the ratings in the conventional tests with those in general intelligence varied considerably, ranging from .136 to .572 in the different forms. Taking into account only the 103 subjects in Series 1 of the experiment and the 105 subjects in Series 2, who took the complete set of tests, the correlations of the new tests with general intelligence ranged from .48 to .64 or averaged about .589; and the correlations of the ordinary tests with general intelligence ranged from .34 to .648 or averaged about .475. Therefore, there was an appreciably higher and more constant correlation in the case of the new tests than that of the ordinary type of written examination.

It must be remembered that the conventional tests in this study were probably not so open to criticism as are most written examinations, since it was impossible for the experimentor not to be conscious of the objectives of the study. Consequently, the construction of the questions, the methods of administration and scoring described in Chapter IV probably rendered the marks more objective than they might have been otherwise. This undoubtedly affected the scores obtained and the correlations based on them.

In addition to deficiencies in general intelligence tests as indicators of general learning capacity, and in both the new and conventional tests as measures of achievement, there are a number of factors like fatigue, sickness, nervousness, fear, attitude toward test, emotional state, distractions, application and concentration which produce variable performances. Courtis[27] estimates that such factors tend to make the scores unreliable indices of attainment in possibly about 10 percent. of the total number of cases.

It is unsafe to draw any far-reaching inferences as to the relative advantages and disadvantages of the two types of tests on the basis of the correlations with general intelligence for the following reasons: first, the lack of positive psychological

[27] Courtis, S. A.: The Gary Public Schools, Measurement of Classroom Products, pp. 355-82.

information concerning the exact nature of general intelligence and specific abilities involved in accomplishment in subject-matter in general and General Science in particular; second, imperfections in the general intelligence and achievement tests as measuring-sticks; third, the fact that different mental abilities are sufficiently independent to render their interrelation a variable quantity, fourth, the lack of definite knowledge regarding the distribution of such abilities with reference to approximation to the ideal Gaussian curve and correlations that should theoretically exist between general intelligence ratings and achievement in subject-matter; fifth, the factors limiting specific performances; and sixth, the small number of cases in this experiment. However, it is confidently expected that if the development of educational measurements continues at its present rate of progress, the time is not far distant when definite conclusions may become justified. It is hoped that at a future date some research workers in the field of educational measurements may find the data presented of value. For their benefit a table of the raw scores in all the tests will be found in the Appendix, Section 5.

Summary

1. From a practical point of view as far as their use in school is concerned, most psychologists agree essentially on the validity of general intelligence tests as the best available measures of educability and of their diagnostic value in predicting accomplishment in school subjects.

2. We are justified in presupposing that abilities in General Science are composites which would be distributed in conformity with the normal probability curve if the scores in a sufficient number of cases could be assembled.

3. It was not possible to include more than 208 pupils who took all the tests given, therefore, a direct investigation of the extent to which the distribution of the scores in both types of tests approached the ideal normal probability curve according to accepted statistical procedure could not be determined.

4. Accordingly, an attempt was made to obtain indirect information of the absolute distribution of the scores in both

kinds of achievement tests with reference to scores in general intelligence examinations.

5. Wood took the records of about 1500 students at Columbia University and made a comparative study of the conventional and new types of tests on the basis of general intelligence ratings. He found that the correlation of the new types of examinations in Contemporary Civilization with general intelligence was about .6, and the correlations of the conventional examinations with general intelligence was between .4 and .5.

6. In the experiment the average correlation of the different new tests in General Science with general intelligence was .589 and that of the conventional tests with general intelligence was .475.

7. However, the limitations of this phase of the study make it unsafe to draw any far-reaching inferences as to the relative advantages and disadvantages of the two types of tests on the basis of their correlations with general intelligence.

CHAPTER VI

A COMPARISON OF THE NEW AND CONVENTIONAL TYPE OF TEST IN GENERAL SCIENCE, BASED CHIEFLY ON THE QUESTIONNAIRE PHASE OF STUDY, EXPERIMENTATION WITH CLASSES AND GENERAL TEACHING EXPERIENCE

A. Construction

1. Realization of Educational Aims and Objectives

New Test.—The questions are constructed with the intention of isolating so far as practicable, abilities in science from other varying abilities such as those in English, spelling, penmanship and drawing. Its formulation compels a closer and sharper analysis of the subject matter in its minute details. The questions are carefully worded so as to point toward a single significant fact or fundamental idea. The emphasis is on the use of facts and principles and intelligent understanding as indicated by applications rather than on mere reproduction of textual material. There are many opportunities to test interpretation, intellectual power and dynamic knowledge since there are more questions per unit of examination period. For example, the six new tests used in the experiment contained 31, 37, 39, 34, 38 and 41 questions respectively, or an average of 36.6 questions. The examination is comprehensive and represents a fair sampling of the field.

There are possibilities of an indefinite subdivision of topics. Standards in the shape of unit-goals can be set up readily and attainments measured scientifically from the point of view of the course of study, the textbooks used and the methods of instruction. The new type of test is an excellent teaching device and in a definite way points out wherein instruction has been ineffective and the parts that require review, emphasis or added explanation. It enables the learner to see clearly the mistakes made, stripped down to their barest word or phrase form.

Conventional Test.—The questions are usually framed so

that they tend to encourage memorization. The scope of the examination is relatively narrow and not fairly representative of the field. There were six questions included in each of the first three conventional tests used in the experiment. The number was reduced to five in the other three conventional tests because it was found that a large percentage of the boys handed in unfinished papers. Vagueness, diffuseness and partial misconceptions characterize the discussions called forth. The specific errors are often hidden among a confusing maze of words. Even if the papers are carefully corrected by the teacher, the pupil may not fully realize just what is wrong with the answers. The mark measures a complex composed of many variable abilities. The conventional test is not well adapted for diagnosis of class and individual abilities and disabilities in subject matter, and is not a refined instrument for the measurement of attainments.

2. Measurement of Accomplishment in Subject Matter

(a) Mechanics of writing as a factor in mark.

New Test.—Legibility and speed in writing are negligible elements in the mark. The mechanics of making a check mark, underscoring a word or phrase, and filling in a number on a dotted line is not of appreciable importance in its effect on performances. There is an opportunity to spend a maximum amount of time in thought and a minimum amount of time in writing.

Conventional Test.—Legibility is an element in the mark. As shown by the results in the questionnaire phase of the study, many teachers are directly or indirectly influenced in rating papers depending upon their difficulty in deciphering them. Speed in writing is also a factor in the mark, especially if the discussions are voluminous and contain irrelevant material. In contrast to the new type of test, there is a relative increase in the amount of time required for writing and a corresponding decrease in the time that may be devoted to unhampered thinking.

(b) The drawing of diagrams as a factor in the mark.

New test.—The student is called upon to make a line, curve or other unitary symbolic corrections on diagrams. Therefore, ability in constructive drawing is not an element in the mark.

Conventional test.—Very often students spend a great deal of time in elaboration of parts that are of minor importance, and the points which would show up their comprehension of the principles involved are either slighted or obscured. The entire diagram may be drawn so badly that whether or not it merits any credit is questionable. Consequently, in many instances it is hard to determine the degree of perfection with reference to any standards, and skill in the making of diagrams is a factor in the rating.

(c) English as a factor in the mark.

New test.—There are no essays small or large to be written. Ability in English is a factor only as a tool in conveying thought in so far as comprehension of verbal instructions and of the printed material on the sheets are concerned. The time allowances are sufficiently liberal to render rate of reading for pupils of high-school standing an unimportant matter. Sharp definition of thought and conciseness of expression are indirectly fostered. The fact that no intricate or elaborate answers are required, involving abilities to interpret, organize, analyze and summarize a body of information, is no disadvantage for the majority of the pupils since the genius would be at the top of the class anyway. Furthermore, there is no reason for believing that a short answer may not be preceded by very complex mental activities. Therefore, accomplishment in creative English is not a factor in the new tests.

Conventional Test.—Students differ in their command of English and in their ability to express their ideas without undue wordiness. They frequently write voluminously on questions they presumably know well and volunteer many irrelevant facts. In recognition of the superiority of the phraseology of the textbook over their own, some of them give extracts verbatim even if these have but a partial or remote bearing on the particular topic under discussion. In consequence, the available time left for answering the other questions is materially shortened. Sometimes disabilities in English interfere seriously with clearness of exposition so that objective scoring is next to impossible. On the contrary, systematic, logically organized answers may mean good memorization without necessarily implying a complete, intelligent under-

standing of the subject. Therefore, in the essay type of examination, the mark includes accomplishment in English.

B. Administration

New Test.—The inherent nature of the new tests lends itself readily to uniformity in administration to all classes and individual pupils. Definite instructions can be given regarding just what is to be done and methods of work. The time can be apportioned equitably among the different parts of the examination. All pupils attempted the six sub-parts of the new tests used in the experiment.

Conventional test.—The structure of the conventional test is not conducive to uniformity in administration to the different classes and pupils. The questions are usually too general to permit specific instructions concerning the precise points for discussion and methods of treatment. About one-fifth of the pupils show inability to divide up the total time among the different questions in accordance with their relative importance, and as a result they do not have time to attempt all of them.

An approximation of the number of unfinished papers in the experiment was made. An arbitrary criterion was applied. If the last question or last two questions were not attempted the paper was counted as unfinished. It was impracticable to differentiate omissions caused by lack of time from those caused by lack of information. No attention was paid to other questions left unanswered. As shown by Table 9 a general average of 22 percent. of the pupils did not have time to finish the examinations.

Table 9

Unfinished Papers in Ordinary Tests in General Science

	Number of Papers	*Number Unfinished*	*Per Cent Unfinished*
Ordinary 1.....	140	44	33
Ordinary 2.....	131	28	21
Ordinary 3.....	115	12	10
Ordinary 4.....	129	48	37
Ordinary 5.....	125	20	16
Ordinary 6.....	107	16	15
All ordinary tests....	747	168	22

C. Objectivity of Scores

New Test.—The formulation of the new type of test compels particular attention to conciseness, definiteness and sharp delimitation of responses in order to make only one answer, usually a word or phrase,—the right one. No partial credits are assigned. The scoring is mechanical and can be done accurately within a comparatively short time by means of stencils or keys of answers. Variability in ratings assigned by different examiners is practically eliminated. Hence, the marks are objective and reliable.

Conventional Test.—The responses are characteristically of the discussion form. The possibility of objective grading is restricted to a variable degree depending on how nearly the nature of the questions permits an analysis of the answers expected into unit-elements. If there is more than one element in the standards established, the personal equation of the marker will affect the ratings. When an answer is partly correct, the mark it is entitled to cannot be determined definitely. This means the assignment of arbitrary partial credits. Teachers tend to overmark for questions answered voluminously and to undergrade brief answers even though they both contain the same ideas. The scoring consumes a great deal of time. It is physically and mentally fatiguing and, especially toward the latter end of the process as attention flags, errors are sure to creep in. Hence, the marks are subjective and unreliable.

D. Opinions of Examinees

At the close of each of the two terms during which the experiment was conducted, after all the tests had been administered, the boys were requested to state frankly in written form which type of test they liked better, and to give reasons for their opinions. Of the 131 boys who expressed themselves on this question in the first part of the study, 120 favored the new type and 11 the usual discussion type of examination, and of the 116 who similarly indicated their preferences in the second part of the study, 111 liked the new type better and 5 thought the essay kind of test more desirable. Grouping all the replies, 231 preferred the new tests and 11 the conventional tests. A summary of the replies follows.

TABLE 10

Reasons given by 231 students in favor of the New Tests

Reason	*Frequency*
1. Saves time	98
2. Less writing, no lengthy answers required	83
3. Easier	48
4. Questions shorter, clearer and easier to understand	44
5. Reminds one of right answer, suggests ideas, and gives hints of correct answers	43
6. Gives more time to think	41
7. More questions, therefore fairer	40
8. More interesting	20
9. Easier for teacher to mark and saves his time	17
10. Poor English and difficulties in expression are not factors in mark	12
11. Guessing permitted	11
12. Better chance to answer all questions	9
13. Misspelled words do not affect grade	6
14. Prevents wandering off subject and writing of much unnecessary material	6
15. Makes you think more quickly	6
16. Grammatical errors do not affect grade	5
17. Poor penmanship does not affect grade	5
18. No mistakes in copying from board due to eye defects or other causes	3
19. Neatness of paper does not affect grade	3
20. Some teachers do not write the questions legibly on the board	1

Reasons given by 11 students in favor of the Conventional Tests

1. Can answer more fully and freely in our own words	4
2. Easier	3
3. Gives more time to think	3
4. Can spend more time on questions you know better	2
5. Questions are more like those in book	1
6. No temptation to answer questions incorrectly	1
7. Not as complicated as New Tests	1
8. Too many interruptions in the New Tests	1

SUMMARY

1. The questions of the new type of test are framed with the intention of isolating so far as practicable abilities in subject matter from other varying abilities such as those involved in the mechanics of writing, drawing of diagrams, English, spelling and the like. The examination is comprehensive and represents a fair sampling of the field. It is well adapted for diagnosis of

class and individual abilities and disabilities. Standards in the shape of unit-goals can be set up and attainments measured scientifically. The conventional test is narrow in scope and the limited number of questions does not constitute a fair sampling of the material of instruction. The discussion-answers involve a complex of abilities, consequently standards in the form of unit-goals are almost impossible to formulate, and accomplishment cannot be measured accurately.

2. The inherent nature of the new test lends itself to uniformity in administration to all classes and individual pupils. Definite instructions can be given regarding just what is to be done and how. The time can be apportioned equitably among the different questions. Scientific procedure in the administration of the ordinary examination is very difficult.

3. There is only one correct answer, usually a word or phrase, for each question in the new test. No partial credits are assigned. The scoring is mechanical and can be done within a short time by the use of a stencil or key of answers. Variability in marking on the part of different examiners is practically eliminated. Therefore, the marks are objective and reliable.

In the usual kind of examination the responses are typically discussions. It is impossible to get teachers to agree on standards of perfection if there is more than one element in the answers expected. The marking is physically and mentally fatiguing, and noticeably subjective and unreliable.

4. With only a few exceptions, the students like the new tests far better than the conventional tests.

CHAPTER VII

GENERAL SUMMARY AND CONCLUSIONS

1. The written examination is an important measure of achievement.

2. The studies of Kelley, Starch and Elliott, Gray and others prove that teachers' marks are subjective and unreliable.

3. Adjustment of marks to make them conform to the normal probability curve treats the symptoms of their unreliability, but does not cure the underlying causes. Therefore, such a procedure is not an adequate solution of the problem.

4. If the practices of the 241 high school teachers who cooperated in the questionnaire phase of the investigation represent a fair sampling of the general situation with respect to written examinations, then the following conclusions seem to be warranted:

a. Written tests are held generally at irregular intervals, upon the completion of major subdivisions of the subject.

b. Ordinarily the examination consists of 10 questions or less.

c. The time allowance for the average test during the term is 40 to 45 minutes. For final examinations this is often 1, 2 or 3 hours.

d. Usually the questions are written on the board. Sometimes, especially for final examinations, they are mimeographed (duplicated) or printed.

e. In a general way penmanship, spelling, English, grammar, paragraphing and other factors affect the marks given by a majority of the teachers.

f. Teachers do not grade papers on a strictly mathematical basis but make arbitrary adjustments for a variety of reasons such as the number of questions attempted, and differences in standards for superior, average and poor students.

5. The 122 sample examinations sent along with the questionnaires furnished many illustrations of imperfectly constructed questions. Some examinations were very long and demanded a considerable amount of writing.

6. The 20 sets of papers representing superior, average and poor students contained examples of lack of uniformity in applying whatever standards seemed to be used, and errors in grading.

7 Standardized tests and scales are objective measures of achievement and have many advantages over the conventional tests. But they also have disadvantages limiting their usefulness, especially in the high school.

8. New tests were devised, modeled after the best of the group intelligence tests, standardized tests and scales and the new type of examination given to students at Columbia University. The aim was to make them more accurate objective instruments for the measurement of educational products than the ordinary tests, and readily adjustable to the content, methods of instruction, and teaching emphasis of the individual teacher. It is intended that the new tests should supplement and not supplant standardized tests and scales involving the minimum essentials of school subjects.

9. An experiment extending over two consecutive terms was conducted with two separate groups of pupils taking General Science, a total of 291 boys. The Terman and Army Alpha Group Intelligence Examinations were given for the purpose of determining their general learning capacity. This was followed by a parallel series of three ordinary and three new tests in General Science, both covering practically the same content and progressively cumulative in nature in order to ascertain their relative advantages and disadvantages as measures of accomplishment.

10. The correlation of the scores in the new tests with those in the general intelligence tests was higher than in the case of the conventional tests. However, the limitations of this part of the experiment make it unsafe to draw any positive inferences on this basis, except to say that the new tests are at least as reliable as the conventional tests.

11. The chief advantages of the new tests over the ordinary tests include a greater number of questions per unit of examination

time, the testing of more unitary abilities in subject matter largely dissociated from other varying abilities, scientific method of administration and objectivity of marks.

12. In proportion as the traditional type of test approaches the standards set by the new type of test in regard to comprehensive sampling of the material of instruction, elimination of abilities other than those under investigation, formulation of unit-goals, scientific method of administration and objectivity in grading, the more reliable it will become as a measuring-stick. But the intrinsic structure of this sort of examination limits, and that of the new test distinctly favors, the realization of the objectives mentioned. Therefore, the new tests are more likely to be refined, precise and adequate instruments by means of which accomplishment may be measured.

APPENDIX

Section 1

Schools Cooperating in the Investigation

1. Alabama
   - a) Birmingham
     - (1) Central High School
   - b) Mobile
     - (1) Mobile High School
2. Arizona
   - a) Tucson
     - (1) Tucson High School
3. Arkansas
   - a) Fort Smith
     - (1) Fort Smith High School
   - b) Pine Bluff
     - (1) Central High School
4. California
   - a) Berkeley
     - (1) Burbank Junior High School
   - b) Fresno
     - (1) Fresno Technical School
   - c) Los Angeles
     - (1) Hollywood High School
   - d) Oakland
     - (1) Fremont High School
   - e) San Francisco
     - (1) Lowell High School
     - (2) Polytechnic High School
   - f) Stockton
     - (1) Stockton High School
5. Colorado
   - a) Boulder
     - (1) State Preparatory School

b) Denver
   (1) Grant Junior High School
   (2) Manual Training High School
   (3) North Side High School

c) Pueblo
   (1) Pueblo High School

6. Connecticut
   a) Bridgeport
      (1) Bridgeport High School
   b) Hartford
      (1) Hartford Public High School
   c) New Haven
      (1) New Haven High School
   d) Norwalk
      (1) Franklin Junior High School
   e) Torrington
      (1) Torrington High School
7. Delaware
   a) Dover
      (1) Dover High School
   b) Wilmington
      (1) Wilmington High School
8. District of Columbia
   a) Washington
      (1) Central High School
      (2) Eastern High School
      (3) McKinley Manual Training School
9. Florida
   a) Jacksonville
      (1) Duval High School
   b) Miami
      (2) Miami High School
10. Georgia
   a) Atlanta
      (1) Girls' High School
      (2) Technological High School

11. Idaho
    a) Lewiston
        (1) Lewiston High School
    b) Pocatello
        (1) Pocatello High School
12. Illinois
    a) Alton
        (1) Alton High School
    b) Aurora
        (1) West High School
    c) Chicago
        (1) Christian Fenger High School
        (2) Crane Technical High School
        (3) Englewood High School
        (4) John Marshall High School
        (5) Tilden Technical High School
    d) East St. Louis
        (1) East St. Louis High School
    e) Elgin
        (1) Elgin High School
    f) Galesburg
        (1) Galesburg High School
    g) Moline
        (1) Moline High School
    h) Rockford
        (1) Rockford High School
13. Indiana
    a) Elkhart
        (1) Elkhart High School
    b) Lafayette
        (1) Jefferson High School
    c) South Bend
        (1) South Bend High School
14. Iowa
    a) Cedar Rapids
        (1) Washington Senior High School
    b) Council Bluffs
        (1) Abraham Lincoln High School

c) Des Moines
   (1) North High School
d) Ottumwa
   (1) Ottumwa High School
e) Sioux City
   (1) Central High School
f) Waterloo
   (1) East Junior High School
   (2) West High School

15. Kansas
   a) Kansas City
      (1) Wilson Academy
   b) Pittsburg
      (1) Senior High School
   c) Salina
      (1) Salina Junior High School
   d) Topeka
      (1) Topeka High School

16. Kentucky
   a) Covington
      (1) Holmes High School
   b) Louisville
      (1) Girls' High School
   c) Owensboro
      (1) Owensboro High School

17. Louisiana
   a) Baton Rouge
      (1) Central High School

18. Maine
   a) Augusta
      (1) Augusta High School
   b) Bangor
      (1) Bangor High School
   c) Bath
      (1) Morse High School
   d) Lewiston
      (1) Jordan High School

e) Portland
(1) Deering High School

19. Maryland
a) Baltimore
(1) Eastern High School
(2) Western High School (Senior)
b) Hagerstown
(1) Washington County Male High School

20. Massachusetts
a) Boston
(1) East Boston High School
b) Brockton
(1) Brockton High School
c) Brookline
(1) Brookline High School
d) Chicopee
(1) Chicopee High School
e) Everett
(1) Everett High School
f) Fall River
(1) B.M.C. Durfee High School
g) Haverhill
(1) Haverhill High School
h) Holyoke
(1) Junior High School
i) New Bedford
(1) New Bedford High School
j) North Adams
(1) Drury High School
k) Pittsfield
(1) Central High School
l) Revere
(1) Revere High School
m) Taunton
(1) Taunton High School

21. Michigan
a) Bay City
(1) Eastern High School

b) Detroit
   (1) Central High School
   (2) East Technical High School
c) Flint
   (1) Flint High School
d) Highland Park
   (1) Highland Park High School
e) Jackson
   (1) Jackson High School
f) Lansing
   (1) Lansing East Junior High School
g) Muskegon
   (1) Muskegon High School
h) Pontiac
   (1) Pontiac High School
i) Saginaw
   (1) Saginaw High School

22. Minnesota
   a) Duluth
      (1) Central High School
      (2) Denfeld High School
   b) Minneapolis
      (1) Central High School
      (2) North High School
      (3) West High School
   c) St. Cloud
      (1) Technical High School
   d) St. Paul
      (1) Central High School
   e) Winona
      (1) Winona High School

23. Mississippi
   a) Laurel
      (1) Laurel High School
   b) Meridian
      (1) Meridan High School

24. Missouri
    a) Kansas City
        (1) Central Junior High School
        (2) Manual Training High School
    b) St. Joseph
        (1) Benton High School
    c) St. Louis
        (1) Central High School
        (2) Yeatman High School
    d) Springfield
        (1) Central High School
25. Montana
    a) Anaconda
        (1) Anaconda High School
    b) Butte
        (1) Butte High School
    c) Great Falls
        (1) Great Falls High School
    d) Missoula
        (1) Missoula County High School
26. Nebraska
    a) Lincoln
        (1) Teachers College High School
    b) Omaha
        (1) Central High School
27. Nevada
    a) Carson City
        (1) Carson City High School
28. New Hampshire
    a) Concord
        (1) Parker Junior High School
    b) Dover
        (1) Dover High School
    c) Manchester
        (1) Manchester High School
    d) Nashua
        (1) Nashua High School

29. New Jersey
    a) Bloomfield
        (1) Bloomfield High School
    b) Camden
        (1) Camden High School
    c) Hoboken
        (1) Hoboken High School
    d) Irvington
        (1) Irvington High School
    e) Jersey City
        (1) Lincoln High School
    f) Kearny
        (1) Kearny High School
    g) Passaic
        (1) Passaic High School
    h) Paterson
        (1) Paterson High School
    i) Perth Amboy
        (1) Perth Amboy High School
    j) North Plainfield
        (1) North Plainfield High School
    k) Trenton
        (1) Junior High School, No. 2.
30. New Mexico
    a) Albuquerque
        (1) Albuquerque High School
    b) Roswell
        (1) Roswell High School
    c) Santa Fe
        (1) Santa Fe High School
31. New York
    a) Amsterdam
        (1) Amsterdam High School
    b) Binghamton
        (1) Central High School
    c) Buffalo
        (1) Lafayette High School

d) Cohoes
   (1) Cohoes High School
e) Gloversville
   (1) Gloversville High School
f) Kingston
   (1) Kingston High School
g) New York
   (1) Bushwick High School (Brooklyn)
   (2) Commercial High School
   (3) De Witt Clinton High School
   (4) Eastern District High School
   (5) The Lincoln School of Teachers College
h) Olean
   (1) Olean High School
i) Oswego
   (1) Oswego High School
j) Rochester
   (1) West High School (Junior)
k) Rome
   (1) Rome Free Academy
l) Syracuse
   (1) Blodgett Vocational High School
m) White Plains
   (1) White Plains High School
n) Yonkers
   (1) Yonkers High School

32. North Carolina
   a) Asheville
      (1) Asheville High School
   b) Charlotte
      (1) Alexander Graham High School

33. North Dakota
   a) Grand Forks
      (1) Grand Forks High School

34. Ohio
   a) Canton
      (1) Central High School

b) Cincinnati
   (1) Walnut Hills High School
c) Cleveland
   (1) East High School
   (2) East Technical High School
   (3) Lincoln High School
d) Dayton
   (1) Steele High School
e) East Cleveland
   (1) Shaw High School
f) Elyria
   (1) Elyria High School
g) Lakewood
   (1) Lakewood High School
h) Lorain
   (1) Lorain High School
i) Mansfield
   (1) Mansfield High School
j) Middletown
   (1) Middletown High School
k) Newark
   (1) Newark High School
l) Springfield
   (1) Springfield High School
m) Youngstown
   (1) Rayen High School

35. Oklahoma
   a) Ardmore
      (1) Ardmore High School
   b) Bartlesville
      (1) Bartlesville Junior High School
   c) Enid
      (1) Enid High School
   d) Muskogee
      (1) Central High School
   e) Tulsa
      (1) Central High School

36. Oregon
    a) Astoria
        (1) Astoria High School
    b) Portland
        (1) Jefferson High School
        (2) Lincoln High School
37. Pennsylvania
    a) Altoona
        (1) Altoona High School
    b) Dunmore
        (1) Dunmore High School
    c) Easton
        (1) Easton High School
    d) Harrisburg
        (1) Camp Curtin Junior High School
        (2) Edison Junior High School
    e) Lancaster
        (1) Boys' High School
    f) Nanticoke
        (1) Nanticoke High School
    g) Philadelphia
        (1) Germantown High School
        (2) Girard College
        (3) Girls' High School
        (4) West Philadelphia High School for Boys
        (5) William Penn High School
    h) Pittsburgh
        (1) Allegheny High School
    i) Reading
        (1) High School for Boys
        (2) High School for Girls
    j) Scranton
        (1) Technical High School
    k) Shenandoah
        (1) Shenandoah High School
    l) Eash Washington
        (1) East Washington High School

38. Rhode Island
    a) East Providence
        (1) East Providence High School
    b) Cranston
        (1) Cranston High School
    c) Providence
        (1) Hope Street High School
        (2) Providence Technical High School
39. South Carolina
    a) Charleston
        (1) Memminger High School
40. South Dakota
    a) Watertown
        (1) Watertown High School
41. Tennessee
    a) Knoxville
        (1) Knoxville High School
42. Texas
    a) Austin
        (1) Austin High School
    b) Dallas
        (1) Oak Cliff High School
    c) Fort Worth
        (1) Fort Worth High School
    d) Galveston
        (1) Ball High School
    e) Houston
        (1) Heights Senior High School
    f) San Antonio
        (1) Main Avenue High School
43. Utah
    a) Logan
        (1) Brigham Young College
    b) Salt Lake City
        (1) Eash High School
44. Vermont
    a) Barre
        (1) Spaulding High School

b) Burlington
(1) Burlington High School

45. Virginia
a) Newport News
(1) Newport News High School
b) Norfolk
(1) Lafayette High School
(2) Maury High School
c) Roanoke
(1) Jefferson High School

46. Washington
a) Bellingham
(1) Whatcom High School
b) Seattle
(1) Lincoln High School
(2) West Seattle High School
c) Spokane
(1) The Lewis and Clark High School
(2) North Central High School
d) Tacoma
(1) Stadium High School
e) Vancouver
(1) Vancouver High School

47. West Virginia
a) Fairmont
(1) Fairmont High School
b) Huntington
(1) Central Junior High School
c) Morgantown
(1) Morgantown High School

48. Wisconsin
a) Fond du Lac
(1) Fond du Lac High School
b) Milwaukee
(1) Riverside High School
(2) South Division High School
c) Racine
(1) Racine High School

d) Sheboygan
   (1) Sheboygan High School
e) Superior
   (1) Superior High School

49. Wyoming
   a) Cheyenne
      (1) Cheyenne High School

SECTION 2

General Science Examination—Ordinary 1

1. If we press an inflated rubber ball and then release it, it will resume its original shape. Why?
2. Describe a cyclone and an anticyclone in the Northern Hemisphere and tell what kind of weather is usually associated with low and high pressure areas.
3. Prove that air occupies space, has weight and exerts pressure.
4. Draw a diagram of an air pump and briefly explain how it works.
5. What is a barometer? What three uses are made of the barometer?
6. How may a simple mercurial barometer be constructed?
7. Define a thermometer. How do we determine the freezing and the boiling points?
8. What is the rule for changing the temperature from one scale to the other? Change 80 degrees Centigrade to the corresponding Fahrenheit reading.
9. Why do drops of water appear on cold-water pipes on some summer days and not on others?
10. Why are grass and other plants often moist in the morning of some days although no recent rain has fallen?
11. Explain the meaning of the terms absolute humidity, relative humidity and dew point.
12. A room has a temperature of 20 degrees Centigrade, 10.12 grams of water vapor are present per cubic meter of air and the saturation point at the same temperature is 17.12 grams of water vapor per cubic meter. What is the absolute and the relative humidity?

13. Give at least two advantages and two disadvantages of daylight-saving legislation.
14. Describe an anticyclone and a cyclone in the Southern Hemisphere.
15. Define evaporation and condensation. Give an example of each.

General Science Examination—Ordinary 2

1. Explain how increased atmospheric pressure and decreased atmospheric pressure influence the boiling point of water. Give a proof or example of each.
2. Under what conditions will water boil at 100 degrees Centigrade? What factors will change the normal boiling point?
3. Explain fully either the principle of the ice machine or the siphon.
4. Explain fully either the principle of the hydraulic press or the lift pump.
5. Define or explain the meaning of buoyancy, density, specific gravity and gravity.
6. Explain why some objects float in water and other objects sink in water.
7. Name four factors influencing the rate at which water and land get warm. Give a brief explanation of each one.
8. What is meant by the mechanical advantage of a lever? If a lever is 12 feet long where must the fulcrum be placed in order to have a 4 pound weight balance a 12 pound weight?
9. What is meant by friction? In what way is friction useful to us? In what way is friction not useful to us?
10. What is meant by atom, molecule, chemical compound and mixture of gases?
11. What physical and chemical changes occur when a candle burns?
12. Define machine, work, efficiency of a machine and friction.
13. What is the principle of a filtration plant? How may water be purified chemically?
14. Explain fully the principle of the siphon.

15. Explain fully land and sea breezes. Name and explain at least two factors influencing the rate at which water and land get warm.
16. What force must be exerted to raise a weight of 1400 pounds if we use a set of pulleys containing eight strands of rope? (Neglect friction).
17. Explain fully the principle of the lift pump.
18. How do impurities affect the boiling and freezing points of water? How does decreased atmospheric pressure affect the boiling point of water? How does increased atmospheric pressure affect the boiling point of water?

General Science Examination—Ordinary 3

1. Change 18 degrees Centigrade to the corresponding reading on the Fahrenheit scale. Change 38 degrees Fahrenheit to the corresponding reading on the Centigrade scale.
2. Draw two diagrams of a lift pump, fully labeled, one showing the action of the valves during the upstroke and the other showing the action of the valves during the downstroke.
3. A room has a temperature of 10 degrees Centigrade, 5.0 grams of water vapor are present per cubic meter of air and the saturation point at the same temperature is 9.33 grams of water vapor per cubic meter. What is the relative humidity?
4. A room has a temperature of 15 degrees Centigrade, 8.5 grams of water vapor are present per cubic meter of air and the saturation point at the same temperature is 12.71 grams of water vapor per cubic meter. What is the relative humidity?
5. A room has a temperature of 12 degrees Centigrade, 7.8 grams of water vapor are present per cubic meter of air and the saturation point at the same temperature is 10.57 grams of water vapor per cubic meter. What is the relative humidity?
6. What is meant by atom, molecule, chemical change, and physical change? Give one example of each.

7. Select either hydrogen or carbon dioxide. Tell how we may obtain a pure supply of the gas selected and give at least four properties of this gas.
8. Describe a method of distilling water. How may we separate a mixture of two liquids such as alcohol and water?
9. What is Pascal's principle? What is Archimedes' principle? Give one use made of each principle.
10. Describe a practical method of purifying the water supply of a large city, and of getting rid of its sewage.
11. If a man exerts a pull equivalent to a force of 75 pounds, how many pounds can he lift if he uses a set of pulleys containing 4 strands of rope? If he uses a lever instead to raise the same weight where must he place the fulcrum if the lever is 5 feet long?
12. What is meant by potential and kinetic energy? Give two examples of each kind of energy.
13. Draw either a diagram of a steam engine or a hydraulic press, fully labeled so as to explain the principles involved.
14. What is meant by open, closed, and short circuit? What is a fuse?
15. What bodies are included in the solar system? Explain eclipses of the sun and the moon.
16. Give the size of the moon, its distance from the earth, the period of rotation around its axis and its temperature conditions.
17. Name all the planets according to their distance from the sun.
18. How can you distinguish a planet from a star? Why do all the stars, except the North Star, seem to rise and set?
19. Give four examples of the fact that all the energy on the earth comes directly or indirectly from the sun.
20. What is the difference between a permanent and electro-magnet? Give the law of magnet poles.
21. Describe either a wet or a dry cell. Give four differences between a permanent and an electro-magnet.

22. How does a planet differ from a star? Explain eclipses of the moon and the sun.
23. Describe a lead storage cell. What are the differences between a dry and a wet cell?
24. Describe a lead storage cell. How would you charge and discharge it? Give the chemical changes involved in both processes.
25. Name the planets either in the order of their size or their distance from the sun.
26. Describe the laboratory experiment on electrolysis of water. What conclusions may we draw from this experiment?
27. Draw a diagram of a steam engine fully labeled so as to explain the principles involved.
28. What is meant by volt, ampere, watt and ohm?

General Science Examination—Ordinary 4

1. In a cyclone discuss the pressure at the center (high or low), direction of the air (clockwise or counterclockwise), usual temperature conditions, direction it travels across the country, and chances for rainfall.
2. If your handkerchief is wet explain what could be done to hasten the drying after all the water is pressed out of it. Why is each thing done?
3. Explain how dew formation differs from rainfall and give causes of each. A room has a temperature of 22 degrees Centigrade, 9.93 grams of water vapor are present per cubic meter of air and the saturation point at the same temperature is 19.22 grams of water vapor per cubic meter. What is the relative humidity?
4. Give the freezing and the boiling points on the Centigrade and Fahrenheit thermometers. Change 12 degrees Centigrade to the corresponding temperature on the Fahrenheit scale, and 100 degrees Fahrenheit to the corresponding temperature on the Centigrade scale.
5. Prove that the air occupies space, has weight, and exerts pressure. The barometer at Omaha reads 28.5 inches and at Greeley, Colorado, the barometer reads 24.6

inches. Which place has the higher altitude, Omaha or Greeley? Give a reason for your answer.

6. What is the normal pressure of the atmosphere at sea level? What is the relation between altitude and barometric pressure which helps us determine the height of mountains? At what height will the atmospheric pressure be reduced to one half? Why will it be reduced?
7. What are the two factors that control movement of the winds? Draw a chart of a low pressure area, showing the kinds of weather in the different portions.
8. What is the difference between the Centigrade and Fahrenheit thermometers? Change 45 degrees Centigrade to the corresponding temperature on the Fahrenheit scale, and 45 degrees Fahrenheit to the corresponding temperature on the Centigrade scale.
9. On what four factors does the rapidity of evaporation depend? Explain each factor.
10. What relation exists between the relative humidity of our rooms and our health? How can we maintain the room at a healthful relative humidity?

    A room has a temperature of 20 degrees Centigrade. At this temperature the saturation point is 17.12 grams of water vapor per cubic meter of air. The dew point is 13 degrees Centigrade. At this temperature one cubic meter of air can hold 11.25 grams of water vapor. What is the relative humidity?
11. Describe the construction of a simple barometer. What is the reading of a barometer at sea level under ordinary conditions? What will cause a lower reading? If the reading of the barometer at the foot of a mountain is 28 inches and at the top 21 inches, what is the height of the mountain?
12. How would you determine the relative humidity of a room? A room has a temperature of 25 degrees Centigrade. At this temperature the saturation point is 22.80 grams per cubic meter of air. Condensation occurs at 10 degrees Centigrade. Air can hold 9.33

grams of water vapor per cubic meter at this temperature. What is the relative humidity?

13. Draw and give the graduations of a Centigrade and a Fahrenheit thermometer. Change 13 degrees Centigrade to the corresponding temperature on the Fahrenheit scale, and 95 degrees Fahrenheit to the corresponding temperature on the Centigrade scale.
14. In a cyclone, tell what you know about the barometric pressure, the direction of the winds, the temperature conditions, and the relative humidity (chances for rainfall).
15. Prove that air has weight, pressure, occupies space, and is influenced by temperature changes.
16. What is the principle of the mercurial barometer? Explain the action of an aneroid barometer. How does a barometer help us to determine altitude, and probable weather?
17. Give the boiling and the freezing points of water on the Centigrade and Fahrenheit thermometers. Change 24 degrees Centigrade to the corresponding temperature on the Fahrenheit scale, and 90 degrees Fahrenheit to the corresponding temperature on the Centigrade scale.
18. How would you determine the relative humidity of a room? A room has a temperature of 21 degrees Centigrade. At this temperature the saturation point is 18.14 grams of water vapor per cubic meter of air. Condensation occurs at 8 degrees Centigrade. At this temperature the saturation point is 8.21 grams of water vapor per cubic meter of air. What is the relative humidity?
19. Draw a diagram to show how convection currents are made use of either in this room or in a top-icing refrigerator, and explain. How does convection of heat differ from conduction of heat?
20. Define evaporation and condensation. What are the factors increasing the rate of evaporation?

21. What is the principle of the mercurial barometer? Explain the action of an aneroid barometer. How long would a water barometer have to be? Why?
22. In an anticyclone, tell what you know about the barometric pressure, the direction of the winds, the temperature conditions and the relative humidity (chances for rainfall).
23. How are the boiling and the freezing points determined on a thermometer? Change 15 degrees Centigrade to the corresponding temperature on the Fahrenheit scale, and 80 degrees Fahrenheit to the corresponding temperature on the Centigrade scale.
24. What is meant by relative humidity? Why should the humidity of a room be increased with the temperature? How can we raise the relative humidity? A room has a temperature of 19 degrees Centigrade. At this temperature the saturation point is 16.14 grams per cubic meter of air. Condensation occurs at 8 degrees Centigrade. At this temperature the saturation point is 8.21 grams of water vapor per cubic meter of air. What is the relative humidity?
25. Give the advantages and disadvantages of daylight saving legislation. Why does the sun give more warmth at the tropics than in places either farther north or south of the equator?

General Science Examination—Ordinary 5

1. Choose one of the following gases:—oxygen, hydrogen, nitrogen. Name the chemicals used in order to obtain a pure supply of the gas selected, give two physical properties, two chemical properties, and two reasons why the gas is important.
2. Select either the hydraulic press or the ice machine. Make a diagram of the machine selected and label fully so as to explain the principles involved. (You may write out an explanation instead). Give two uses of the machine.
3. Define or describe the lever and the pulley. A lever is 48 inches long, the fulcrum is 6 inches from a weight of

2400 lbs. How much force must be applied at the other end to just move the weight?

4. Give the factors influencing the boiling and the freezing points of water. Tell how each factor affects the boiling and freezing points. Change 95 degrees Fahrenheit to the corresponding temperature on the Centigrade scale, and 52 degrees Centigrade to the corresponding temperature on the Fahrenheit scale.
5. Explain or define density and buoyancy. Why can a submarine be made to submerge in water and rise to the surface again?
6. If a crowbar is 10 ft. long, where must the fulcrum be placed so that a force of 100 lbs. will raise a weight of 900 lbs? Draw a set of pulleys by which with a force of 150 lbs. you can raise a weight of 600 lbs.
7. Explain what is meant by hard and soft water. How can you make the hard water soft? Describe the principle of a filtration plant. What chemicals are used to kill germs in water?
8. Define buoyancy and density. If a substance floats in water what determines how far it will sink in the water? If it sinks in water what is the difference between its weight in the air and in the water?
9. What is meant by atom and molecule? What is the effect of heat and cold on solids, liquids and gases? How do we explain this effect by the molecular theory?
10. Define or explain the meaning of cyclone, relative humidity, isobar and isotherm. Give at least two uses of a barometer.
11. Why can you float more easily on salt water than on fresh water? Why is it possible for an iron ship to float? What is the average density of the iron ship compared to that of water?
12. What is meant by mechanical advantage of a machine? How do we determine the efficiency of a machine? Make a drawing of a set of pulleys by which a force of 60 lbs. can raise a weight of 240 lbs. (Ignore friction).
13. Make a diagram of an artificial ice machine and label all

the parts so as to explain fully the principles involved. (You may write out an explanation instead).

14. Name four ways of purifying water. Describe the best method for a large city. How may sewage be best disposed of by a large city like Philadelphia?
15. Explain or define the molecular theory and the atomic theory. What is meant by physical change and by chemical change? Give an example of each.
16. Make a diagram of a hydraulic press, fully labeled so as to explain the principles involved. (You may write out an explanation instead). If the area of the large piston is 200 sq. in., what force will 10 lbs. pressure on the small piston exert on the large piston?
17. Name four gases present in the air and give the approximate per cent. of each. Which of the gases in the air helps to make things burn? What is oxidation? Give two examples.
18. Select either nitrogen or oxygen. What chemicals may be used to obtain a pure supply of the gas selected? Give two physical properties and two chemical properties. Give two reasons why the gas is important.
19. Explain or define buoyancy and density. Describe the dry and wet bulb thermometer method of determining relative humidity.
20. Draw a diagram of a set of pulleys so that a force of 130 lbs. can raise 260 lbs. (Ignore friction). Change 66 degrees Fahrenheit to the corresponding temperature on the Centigrade scale, and 48 degrees Centigrade to the corresponding temperature on the Fahrenheit scale.
21. Explain or define atom, molecule, chemical change, and physical change. Give an example of each.
22. What is meant by buoyancy? Explain briefly what happens in each of the following cases:—
    a. Cork, density .6 grams per cubic centimeter, is put in water.
    b. Hard wood, density 1.0 gram per cubic centimeter, is put in water.

c. Iron, density 7.2 grams per cubic centimeter, is put in water.

23. Explain or define a siphon. How is the flow of the liquid started? What determines the height it will raise the liquid over an elevation or obstacle? What causes the flow to go on, and when does the flow stop?
24. Define pulley, work, mechanical advantage of a machine, and efficiency of a machine. Give one example of each.
25. Give four reasons why land and sea do not get heated at the same rate. Explain land and sea breezes.

General Science Examination—Ordinary 6

1. Name all the planets either according to size or distance from the sun. Explain eclipses of the sun and the moon.
2. Give a brief explanation of the molecular theory, atomic theory, Archimedes' principle and density.
3. Draw either a diagram of a steam engine or a hydraulic press, fully labeled so as to explain the principles involved. A man pulling with a force of 150 lbs. on the end of a rope of a set of pulleys having a mechanical advantage of 6, can raise only 850 lbs. What is the efficiency of the machine?
4. Make a diagram of an incandescent lamp with the current supplied by four cells in parallel. How is the light produced?
5. State how you would prepare a supply of carbon dioxide and hydrogen. Give four ways in which these gases differ from each other.
6. Define buoyancy and density.
   A substance has a volume of 120 cubic centimeters and weighs 108 grams. Is it heavier or lighter than water? Give a reason for your answer.
7. How does a planet differ from a star? Name all the planets either according to size or distance from the sun.
8. How do impurities affect the boiling and freezing points of water? How does decreased atmospheric pressure

affect the boiling point of water? How does increased atmospheric pressure affect the boiling point of water?

9. Define machine and mechanical advantage of a lever. A boy pushing down at one end of a lever 6 feet long, pries up a stone weighing 100 pounds. The fulcrum is 2 feet from the stone. How great is the force exerted by the boy?
10. Describe a permanent magnet and an electromagnet. What are the chief differences between permanent magnets and electromagnets?
11. What heavenly bodies are included in the solar system? Explain eclipses of the sun and the moon.
12. Draw either a diagram of an ice machine or a steam engine, fully labeled so as to explain the principles involved.
13. Define lever. Describe the three classes of levers and give one example of each.

    A boy sits on a see-saw 30 inches from the fulcrum and balances another boy, 75 lbs. in weight, who sits 42 inches from the fulcrum. How much does the first boy weigh?
14. What is Archimedes' principle? How can you prove it? What is meant by density? How can you find the density of a piece of aluminum?
15. Make a diagram of an electric bell with the current supplied by four cells in series.
16. Draw a diagram of a steam engine, fully labeled so as to fully explain the principles involved.
17. What is meant by open circuit, closed circuit and fuse? Describe a dry or wet cell and explain how the electricity is produced.
18. State the size of the moon, its distance from the earth, and describe its temperature conditions. How is an eclipse of the moon caused?
19. How would you distinguish between jars filled respectively with carbon dioxide, hydrogen, nitrogen and oxygen?
20. Define work, energy and power.

    A lever is 6 feet long. The fulcrum is 1 foot from a

weight of 150 lbs. How much force must be applied at the other end to just move the weight?

21. How does the atomic theory explain chemical changes? How does the molecular theory explain expansion and contraction of substances when they are subjected to changes of temperature?

    State which of the following changes are chemical and which are physical:—exploding of gunpowder, melting of ice, magnetization of iron, and digestion of food.

22. Describe either a wet or a dry cell. How is the electricity produced? What is the law of magnetic action?

23. Why does the sun rise in the east and set in the west? Why do all stars except the North Star rise in the east and set in the west?

24. An object weighs 120 grams in air and 100 grams in water. What is its density?

    A man pulling with a force of 125 lbs. on the end of a rope in a set of pulleys having a mechanical advantage of 8 can raise only 950 lbs. What is the efficiency of this machine?

25. How does a thermos bottle keep hot things hot and cold things cold?

    Describe either how an iceless cooler works or distillation of water.

Ordinary Examinations in General Science
Distribution of Questions

First Series—February to June 1922

Class	*Ordinary 1*	*Ordinary 2*	*Ordinary 3*
1	4, 5, 7, 9, 11, 12	1, 3, 6, 8, 10, 12	6, 11, 13, 17, 19, 20
2	4, 5, 7, 9, 11, 12	1, 3, 6, 8, 10, 12	3, 7, 9, 13, 21, 22
3	1, 4, 7, 12, 14, 15	2, 3, 4, 5, 9, 11	11, 14, 16, 20, 23, 26
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5	2, 3, 6, 8, 10, 12	1, 3, 6, 7, 8, 10	4, 11, 12, 24, 25, 27
6	2, 3, 6, 8, 10, 12	13, 14, 15, 16, 17, 18	1, 5, 7, 10, 11, 27

Second Series—September 1922 to January 1923

Class	*Ordinary 4, 5, and 6*
1	1, 2, 3, 4, 5
2	6, 7, 8, 9, 10
3	11, 12, 13, 14, 15
4	16, 17, 18, 19, 20
5	21, 22, 23, 24, 25

SECTION 3

Abstract of Correct Answers to the Ordinary General Science Examinations

Ordinary 1

1. Increased air pressure in the rubber ball on pressure, more than 15 lbs. to the sq. in.; resumes original shape on releasing it because air pressure inside and outside of the rubber ball again become equal.
2. Cyclone—large low pressure area, air moving counter-blockwise, the entire area moving generally eastward, associated with warm, rainy weather. Anticyclone—large high pressure area, air moving clockwise, the entire area moving in a general easterly direction, associated with colder, fair weather.
3. It is not possible to fill a bottle with water unless the air is permitted to escape. A collapsed football weighs less than an inflated football. A rubber membrane stretched over a bell-jar open at the top is flat if the air pressure within the bell-jar and outside of it is the same; if some of the air is exhausted from the interior of the bell-jar then the membrane bulges inward; if the air pressure is increased within the bell-jar, then the membrane bulges outward.
4. Diagram showing cylinder, piston, piston rod, valves; application of air pressure; action of valves during upstroke and downstroke.
5. A barometer is an instrument for measuring air pressure, usually containing mercury as the fluid, and graduated so that the top of mercury column may be easily read; used to measure atmospheric pressure, to calculate

elevation above sea level, and to help in weather prediction.

6. Use a glass tube about three feet long with one end closed; fill with mercury, close the open end with the finger, invert the tube and place the open end in a cup of mercury; remove the finger.
7. A thermometer is an instrument for measuring temperature in degrees; the boiling point is determined by placing the instrument in steam and the freezing point is determined by placing the instrument in melting ice.
8. C equals 5/9 (F-32), or equivalent formula; 176 degrees F.
9. The relative humidity is greater on some days than on others. Air coming in contact with cold-water pipes is cooled, contracts and that decreases its capacity for holding water vapor.
10. The relative humidity is greater on some days than on others. Air is cooler in the evening and therefore contracts and that decreases its capacity for holding water vapor.
11. Absolute humidity is the actual amount of water vapor present in 1 cubic meter of air at a given temperature. Relative humidity is the ratio of the number of grams of water vapor present in 1 cubic meter of air at a given temperature compared to what it can hold if saturated at the same temperature. Dew point is the temperature at which a given space would be saturated by the water that it contains and below which the water will begin to condense.
12. 10.12 grams per cubic meter; 59%.
13. Daylight saving legislation saves the cost of artificial light, conserves natural light during working hours, interferes with one's habits, confusing, farmers object.
14. Air moves clockwise in cyclone, and counterclockwise in anticyclone. (Otherwise as answered in number 2.)
15. Evaporation is the change of a liquid to the gaseous form, as in water to steam; condensation is the change of a gas to the liquid form, as in steam to water.

Ordinary 2

1. Increased atmospheric pressure raises the boiling point; boiling water in a boiler; decreased atmospheric pressure lowers the boiling point; boiling water at the top of a mountain.
2. Water will boil at 100 degrees C. if the water is pure and the atmospheric pressure is 15 lbs. to the sq. in.; impurities in the water and increased or decreased atmospheric pressure.
3. Ice machine—diagram fully labeled, or discussion of the following:—ammonia in a pump under pressure of about 155 lbs. to the sq. in., condensation of the ammonia into a liquid, cooling pipes, liquid ammonia changes into a gas and extracts heat from the brine which in turn cools the pure water and forms ice due to cooling by evaporation.

   Siphon—atmospheric pressure is the force involved in the action, the siphon must be filled with the liquid either by applying suction or by filling it with the liquid, the flow continues until the level of the liquid is the same on both sides, or the upper vessel is emptied, the short arm of the siphon may be 34 ft. in the case of water.
4. Lift pump—diagram fully labeled, or explanation covering the following points:—atmospheric pressure the force involved in the action, position and action of the valves during downstroke and upstroke, pump will work to a height of about 30 feet.

   Hydraulic press—diagram fully labeled, or explanation covering the following points:—pressure in a liquid is transmitted equally in all directions, the area of the two pistons bear a certain relation to each other (if they are to each other as 100 to 1, a pressure of 1 gram exerted by the smaller piston on the water surface beneath it would be transmitted undiminished to each of the 100 equal areas at the larger piston and might support a weight of 100 grams, the smaller piston moves 100 times the amount that the larger piston moves).

5. Buoyancy—upward pressure of a liquid or gas on objects immersed. Density—mass or quantity (weight) of matter per unit of its volume. Specific gravity—ratio of the weight of a body to that of an equal volume of water.

   Gravity—the tendency of bodies to fall toward the center of the earth.

6. Some objects float in water because their specific gravity or density is less than that of water and they sink until they displace their own weight in water. Other objects sink in water because they have a specific gravity or density greater than that of water, and they lose in weight depending upon the amount of water displaced.

7. Land gets warm sooner than water for the following reasons:—
   a. Land is a better conductor of heat than water.
   b. Reflection of the rays of the sun is less in the case of water.
   c. Penetration of the rays of the sun is less in the case of water.
   d. Water moves and the heat is distributed more widely than in the case of land.

8. Mechanical advantage of a lever is the ratio of the force to the resistance, or the ratio of the force arm to the resistance arm. 3 feet from the 12 lb. weight.

9. Friction is the resistance offered when two bodies move on each other. It is useful in walking, running, machines run by belts, etc., and not useful when parts of a machine are thereby worn out, heat produced, etc.

10. Atom—one of the indivisible parts of which all matter is supposed to be made up of.

    Molecule—the smallest part of a substance that can exist separately.

    Chemical compound—a substance that can be separated into two or more substances.

    Mixture of gases—two or more gases mixed in any proportion, not united chemically.

11. Physical—changing of the wax to liquid and gaseous forms. Chemical—formation of water vapor and carbon dioxide.
12. Machine—device for facilitating the doing of work.
    Efficiency—ratio of the work done or energy given out to the work or energy put into the machine.
    Work—force acting through distance.
    Friction—(see number 9).
13. Filtration plant—water made to pass through different layers (very fine sand, coarse sand, gravel, pebbles, stones), an action which removes the impurities and many of the bacteria.
    Chemical purification—alum to clear the water; sodium hypochlorite to kill the bacteria.
14. Answered in number 3.
15. Sea breezes during day—land heats more quickly than the sea, air over land becomes warmer and lighter than air over sea, heavier, colder air above water flows over land pushing the lighter, warm air upward.
    Land breezes at night—land cools more quickly than water and the reverse of the above process takes place.
    Any two factors given under number 7.
16. 175 lbs.
17. Answered in number 4.
18. Impurities raise the boiling point and lower the freezing point. Increased atmospheric pressure raises the boiling point and decreased atmospheric pressure lowers the boiling point.

Ordinary 3

1. 64.4 degrees F; 3.3 degrees C.
2. Answered under Ordinary 2, number 4.
3. 53%.
4. 67%
5. 74%.
6. Atom and molecule—defined under Ordinary 2, number 10.
    Atom—oxygen, hydrogen, etc.
    Molecule—finest particle of water, salt, etc.

Chemical change is any change in a substance in which the molecule is changed by atoms being taken away from it, added to it, or exchanged for others. Example—water vapor and carbon dioxide formed during the burning of a candle.

Physical change is a change which does not alter the nature or properties of a substance, but only the appearance. Example—the change of water to steam or ice.

7. Carbon dioxide—hydrochloric acid and calcium carbonate; colorless, odorless, tasteless, 1½ times as dense as air, soluble in water, turns lime water milky, does not burn, does not support combustion.

   Hydrogen—sulphuric acid and zinc; colorless, tasteless, odorless, scarcely soluble in water, lightest substance known, burns, combining with oxygen to form water, does not support combustion.

8. Distillation of water—Liebig's Apparatus used; process of boiling a liquid and condensing the vapor formed back again into a liquid.

   Mixtures of different liquids having different boiling points may be separated by boiling at a temperature at which the one having the lower boiling point will be vaporized first. Alcohol has a lower boiling point than water.

9. Pascal's Principle—pressure applied anywhere to a body of confined liquid is transmitted by the liquid so as to act with undiminished force on every unit of area of the containing vessel.

   Example of use—hydraulic press, etc.

   Archimedes' Principle—a body immersed in a liquid is pushed up by a force equal to the weight of the liquid that it displaces.

   Example of use—floating bodies, floating of iron ships, etc.

10. Filtration plant—answered in Ordinary 2, number 13.

    Disposal of sewage—every house connected with underground sewers in every street; New York pours its sewage into harbor, Chicago into the Illinois River

through the Chicago Drainage canal; Cleveland into Lake Erie; in many inland cities the installation of sewage disposal plants purifies the sewage by action of friendly bacteria.

11. 300 lbs.; 4 ft. from the 75 lbs. force.

12. Potential energy—stored up energy (position, tension, chemical composition); weights in a clock run by weights; raising any object gives it potential energy.
Kinetic energy—energy of motion; cannon ball in motion, falling waters of Niagara Falls, are examples.

13. Diagram of steam engine, fully labeled, or explanation covering the following points:—steam boiler, expansive force of steam; steam chest, relative action of the slide-valve, eccentric rod and eccentric wheel, and the piston, piston-rod and crank, the fly-wheel.
Hydraulic press—Answered in Ordinary 2, number 4.

14. Open circuit—break in the path traversed by the current.
Closed circuit—no break in the path traversed by the current.
Short circuit—a path of low resistance established between any two points, thus shortening the distance traveled by the current.
Fuse—a safety device made of metal (tin, lead) which melts at a low temperature. When the current becomes too strong the fuse wire melts, thus automatically breaking the circuit.

15. Sun and the bodies that revolve around it (planets, their satellites, and planetoids).
Eclipse of the sun—moon between the earth and the sun.
Eclipse of the moon—earth between the sun and the moon.

16. Moon—diameter about 2000 miles; distance from earth, 240,000 miles; rotation around axis—once a month; temperature conditions—varies from near boiling point to below the freezing point during lunar day.

17. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune.

18. Star—point of light, twinkling light, relatively fixed, furnishes own light and heat. Planet—definite spherical shape, steady light, moves around sun, reflected light.

    All stars seem to rise and set for the same reason that our sun rises and sets (rotation of earth around sun). The North Star does not because it is in line with the North Pole.

19. Coal—energy of sunlight stored up. Water power—energy of sunlight causes evaporation of water, clouds form, rain falls over elevated portions of earth, in dropping to the lower levels forms source of water power.

    Wind power—sun heats air over different parts of the earth unequally and currents and winds are produced.

    Energy of our bodies—the food we eat comes directly or indirectly from plant life. (Plants are able to build up the complex compounds forming its tissues by the action of sunlight.)

20. Permanent magnet—steel, retains magnetism indefinitely, relatively weak, practical uses limited.

    Electro-magnet—soft iron, retains magnetism while current is flowing, powerful, practical uses many.

    Law of magnets—like poles repel, unlike poles attract.

21. Wet cell—dilute sulphuric acid, plate of zinc forming the negative pole, plate of copper forming the positive pole, contained in a battery jar.

    Dry cell—zinc cup forms the negative pole, and contains sal ammoniac and a carbon rod forming the positive pole, surrounded by a mixture of black manganese dioxide and powdered carbon.

    Difference between a permanent and electro-magnet —answered in number 20.

22. Answered in numbers 18 and 15.

23. Lead storage cell—before charging there are two lead plates immersed in dilute sulphuric acid, contained in a battery jar. Charging—connect with outside source of electricity,wet or dry cells, and the lead plates become changed to lead peroxide, positive pole, and spongy lead, negative pole. As the lead storage cell is discharged or used the

flow of electric current is in opposite direction and the two plates are reduced to lead again.

Differences between a dry and wet cell—answered in number 21.

24. Answered in number 23 (more details regarding the chemical changes during charging and discharging than in number 23.)
25. Planets in order of distance from sun—answered in number 17. Planets in order of size—Jupiter, Saturn, Neptune, Earth, Venus, Mars, Mercury.
26. Electrolysis of water—Hofmann Apparatus used, dilute sulphuric acid added to the water to make it a conductor, electric current passes through the water between platinum electrodes, the water breaks up into hydrogen and oxygen.

    Conclusions—water is not a good conductor of electricity, it can be broken up by an electric current, and water is made up of hydrogen, two parts, and oxygen, one part.
27. Steam engine—answered in number 13.
28. Volt—unit of electrical pressure.

    Ampere—unit of electrical current or rate of flow.

    Watts—unit of electrical power (volts times amperes).

    Ohm—unit of electrical resistance.

Ordinary 4

1. Answered in Ordinary 1, number 2 and 14.
2. Factors increasing rate of evaporation:—heat, large area exposed to air, winds, dry air (low humidity).
3. Dew formation:—fall of temperature at night, point is reached at which dew or moisture is condensed out from the air and deposited on the ground, grass, etc.

    Rainfall:—chilling of air which contains a certain amount of moisture due to rising of air into higher and colder levels, or due to meeting a colder current of air. 51%.
4. Centigrade thermometer:—freezing point 0 degrees, boiling point 100 degrees.

Fahrenheit thermometer:—freezing point 32 degrees, boiling point 212 degrees.

53.6 degrees F and 37.7 degrees C.

5. Answered in Ordinary 1, number 3.

   Omaha has the higher altitude. For each 900–1000 ft. above the sea level there is a fall of 1 inch in the reading of the mercurial barometer.

6. Drop of 1 inch in the reading of the mercurial barometer for every 900–1000 ft. above the sea level; 4 miles above the sea level; one-half of the atmosphere is within four miles of the surface of the earth.

7. High and low areas and rotation of the earth on axis.

   Low area or cyclone:—low pressure area; movement of air counter-clockwise; warm, weather and precipitation in the eastern part, and cooler weather in the western part.

8. Answered in number 4. 113 degrees F. and 7.2 degrees C.

9. Answered in number 2.

10. Low relative humidity of the air causes discomfort, ill health, catarrh, colds and other diseases of the mucous membrane. Placing of pans of water, wet cloths over the radiators, or opening of the steam radiators will raise the relative humidity. 65%.

11. Answered in Ordinary 1, number 6. 30 inches; the approach of a low area or cyclone; about 7000 ft.

12. Wet and dry bulb thermometer method:—

    Two thermometers, bulb of one is dry, that of the other is kept moist, cooling by evaporation, wet bulb indicates a lower temperature unless air is saturated, consultation of tables, determination of relative humidity. 40%.

13. Answered in number 4. 55.4 degrees F. and 35 degrees C.

14. Answered in number 1.

15. Answered in Ordinary 1, number 3.

    Laboratory experiment—air expands on being heated and contracts on being cooled.

16. Mercurial barometer:—Atmospheric pressure at sea level,

under normal conditions, will support a column of mercury 30 inches in height.

Aneroid barometer:—Metallic box, partial vacuum in the interior, changes in atmospheric pressure affects the outer case, this acts upon a system of levers connected to pointers.

Gradual steady rise in the barometric reading indicates settled weather, gradual steady fall in the barometric reading indicates unsettled or wet weather.

17. Answered in number 4. 75.2 degrees F. and 32.2 degrees C.

18. Answered in number 12. 45%.

19. In a refrigerator convection currents are produced and the coldest part is just below the ice. The warmest part is above the ice.

Convection of heat is the transmission of heat by means of a current (winds and ocean currents). Conduction of heat is the transmission of heat through a body from molecule to molecule (heating of a piece of iron in a flame).

20. Answered in Ordinary 1, number 15, and in Ordinary 4, number 2.

21. Answered in number 16.

A water barometer would have to be more than 34 feet in length. Atmospheric pressure will support a column of water 33–34 feet in height.

22. Answered in Ordinary 1, number 2 and 14.

23. Boiling point—thermometer put in steam.

Freezing point—thermometer put in melting ice. 59 degrees F. and 26.6 degrees C.

24. Answered in Ordinary 1, number 11.

Air expands when the temperature goes up, its capacity for holding water vapor increases and the relative humidity drops.

Answered in number 10. 50%.

25. Answered in Ordina ry 1, number 13.

Rays of the sun are more dir ect at the tropics.

Ordinary 5

1. Oxygen—potassium chlorate and manganese dioxide; colorless, odorless, tasteless, slightly soluble in water; does not burn, supports combustion; forms 1/5 of the atmosphere, 8/9 by weight of water.

   (Similar plan of treatment for N and H, if selected instead).
2. Answered in Ordinary 2, number 3 and 4.

   Uses—compression of cotton into bales, hydraulic elevators, etc.
3. Lever is a rigid bar or rod free to turn about a fixed point called a fulcrum. Pulley is a grooved wheel or sheave turning on an axis in a frame or block. 342.8 lbs.
4. Dissolved substances like salt raises the boiling point of water and lowers the freezing point of water. Increased atmospheric pressure raises the boiling point of water. Decreased atmospheric pressure lowers the boiling point of water.

   35 degrees C. and 125.6 degrees F.
5. Density of a body is its mass per unit volume, or weight of a body in grams per c.c. compared to the weight of the same volume of water. Buoyancy is the upward push or force found in all liquids and gases.

   Submarine—to submerge, water is admitted into special compartments until the average density is equal to or slightly greater than that of water; to rise to the surface, water is forced out of these special compartments by compressed air until the average density is slightly less than that of water.
6. 1 ft. from the 900 lbs. weight. Set of pulleys containing 4 strands of rope.
7. Hard water contains minerals (lime, sulphates of calcium and magnesium, etc.) in solution. Soft water does not contain dissolved minerals. Boiling will get rid of temporary hardness. Borax and washing soda will neutralize permanent hardness.

   Answered in Ordinary 2, number 13. Sodium hypochlorite.

8. Answered in number 5.

   The substance will sink until it displaces its own weight in water. The body will lose in weight equal to the weight of the water displaced.

9. Answered in Ordinary 2, number 10.

   Heat causes expansion and cold causes contraction.

   Molecular theory—heat causes the molecules to move faster, they collide with one another with greater force and rebound farther, therefore the body takes up more space or expands; cold causes the molecules to move more slowly, they do not collide with one another with as much force and the rebound is less, therefore the body takes up less space or contracts.

10. Answered in Ordinary 1, number 2 and 11.

    Isobars are lines connecting regions of the same air pressure.

    Isotherms are lines connecting regions of the same temperature.

    Determination of atmospheric pressure, height above sea level, and weather prediction.

11. The density of salt water is greater than that of fresh water, therefore the force of buoyancy is greater and the displacement is less. An iron ship is so shaped that it displaces a great deal of water. The average density is less than 1.0 gram per cubic centimeter.

12. Mechanical advantage of a machine is the ratio of the resistance to the force applied. The efficiency of a machine is the ratio of the useful work gotten out of a machine to the total work put into it.

    Set of pulleys containing four strands of rope.

13. Answered in Ordinary 2, number 3.

14. Answered in Ordinary 2, number 13.

    Sewage disposal—septic tank involving action of bacteria of decay and contact filter beds involving action of oxidizing bacteria.

15. Answered in number 9.

    Atomic theory—the smallest particles of matter which take part in chemical changes and which do not divide

during these changes are called atoms. There are about 80–90 different atoms.

Physical changes—changes in which a substance does not lose the characteristics by which we identify it (molecules are not broken up or changed), as in melting a piece of lead and changing water to steam.

Chemical changes—changes in which a substance loses its identity and substances with new characteristics are formed (molecules are broken up or changed), as in burning coal and the rusting of a nail.

16. Answered in Ordinary 2, number 4.

17. Nitrogen 78%, oxygen 21%, argon 0.9% and carbon dioxide 0.04%.

Oxygen helps make things burn. Oxidation is the chemical combination of a substance with oxygen, as in the burning of a splinter and the rusting of iron.

18 Answered in number 1.

19 Answered in number 5 and in Ordinary 4, number 12.

20. Diagram of one movable pulley.

18.8 degrees C. and 118.4 degrees F.

21. Answered in Ordinary 3, number 6, and Ordinary 5, number 15.

22. Answered in number 5.

0.4 of it is above water and 0.6 under water.

Entirely submerged.

Sinks—loses in weight depending upon amount of water displaced.

23. Siphon—a device for transferring liquids from a given level to a lower level over an intervening elevation or obstacle. The flow may be started either by suction or by filling the siphon with the liquid. The height of the column of liquid the atmospheric pressure can support is 33 feet in the case of water and 30 inches in the case of mercury. Atmospheric pressure is the force causing the flow to go on, and the flow stops when the liquid is at the same level in both receptacles or when the upper one is empty.

24. Answered in number 3, and in Ordinary 2, number 12.
25. Answered in Ordinary 2, number 7 and 15.

Ordinary 6

1. Answered in Ordinary 3, numbers 17, 25 and 15.
2. Answered in Ordinary 5, numbers 9, 15 and 15; Ordinary 3, number 9.
3. Answered in Ordinary 3, number 13, Ordinary 2, number 4. 94.4%.
4. Diagram of incandescent lamp, fully labeled, or explanation covering the following points:—The current is conducted to and from the lamp by copper wires. It is conducted through the glass by means of short wires usually made of platinum. The filament is made of tungsten enclosed in an exhausted glass globe or in one filled with nitrogen.

   The connecting wires join positive pole to negative pole when cells are connected in series.

   The passage of the current through the filament, which has a high resistance, heats it to a state of incandescence. The filament is enclosed in a vacuum or an inert gas like nitrogen within a glass bulb to prevent it from burning.
5. Answered in Ordinary 3, number 7.
6. Answered in Ordinary 5, number 5.

   The density of the substance is 0.9 grams per c.c. therefore it is lighter than water.
7. Answered in Ordinary 3, numbers 18, 17 and 25.
8. Answered in Ordinary 5, number 4.
9. Answered in Ordinary 2, numbers 12 and 8.

   The force exerted by the boy is equal to 50 lbs.
10. Answered in Ordinary 3, number 20.
11. Answered in Ordinary 3, number 15.
12. Answered in Ordinary 2, number 3; Ordinary 3, number 13.
13. A lever is a rigid bar or rod free to turn about a fixed point called a fulcrum.

    Lever of the 1st class—fulcrum between force and resistance or weight. (Example—scissors).

Lever of the 2nd class—resistance or weight between fulcrum and force. (Example—nutcracker).

Lever of the 3rd class—force between fulcrum and resistance or weight. (Example—sugar tongs).

The first boy weighs 105 lbs.

14. Answered in Ordinary 3, number 9.

Bucket and cylinder experiment proving that the loss of weight of the cylinder in water is equal to the weight of the water displaced.

Answered in Ordinary 5, number 5.

Divide the weight of the aluminum in air by its volume in c.c. which is numerically equal to the loss of weight in water.

15. Diagram fully labeled showing the battery, consisting of cells connected in series—the connecting wires joining positive pole to negative pole, the push button, and the bell including the electro-magnets, the spring, the armature, the contact screw, hammer and gong.
16. Answered in Ordinary 3, number 13.
17. Answered in Ordinary 3, number 14.
18. Answered in Ordinary 3, numbers 16 and 15.
19. Carbon dioxide—turns lime water milky; 1½ times as heavy as air.

Hydrogen—burns, combining with oxygen to form water; lightest gas.

Nitrogen—inert gas; slightly soluble in water; slightly lighter than air.

Oxygen—supports combustion; slightly soluble in water; slightly heavier than air.

20. Work is force acting through space. Energy is the capacity or ability to do work. Power is the time rate of doing work. A force equal to 30 lbs. is required.
21. Answered in Ordinary 2, number 10, and in Ordinary 5, numbers 15 and 9.
22. Answered in Ordinary 3, numbers 20 and 21. The electricity is produced by the transformation of the energy of chemical action into the electrical energy of a current.
23. Answered in Ordinary 3, numbers 18 and 15.

24. The density of the object is 6 grams per c.c.

The efficiency of the machine is 95%.

25. A thermos bottle consists of two bottles one inside the other, with a vacuum between the two. Since a vacuum does not conduct heat this keeps the inside heat from getting out, in case of hot liquids, and the outside heat from getting in, in the case of cold liquids.

Distillation of water is a process of boiling the liquid and condensing the vapor back again into a liquid by means of a Liebig Apparatus or similar device.

(No student attempted to explain the principle of the iceless cooler.)

Section 4

Scoring Key for General Science Examination

New 1

Part A.

1–true, 2–false, 3–false, 4–false, 5–true, 6–true, 7–false, 8–true, 9–true, 10–false.

Part B.

1–60 bs., 2–25%, 3–anticyclone, 4–15 inches, 5–condensation.

Part C.

1–a, 2–d, 3–c, 4–b, 5–b.

Part D.

1–c, 2–a, 3–d, 4–b and d.

Part E.

1– 4, 2, 1, 5, 3.

2– 68 degrees C.

Part F.

1. The coldest part is directly under the ice.
2. Bubbles arising from the tube under the water are omitted.
3. Correct.
4. Convection currents should go in the opposite direction.

Maximum Credit—31 points.

Scoring Key for General Science Examination

New 2

Part A.

1–true, 2–false, 3–true, 4–false, 5–true, 6–true, 7–false, 8–true, 9–false, 10–true.

Part B.

1–75%, 2–2000 ft. lbs., 3–100,000 grams, 4–400 lbs., 5–50%.

Part C.

1–diffusion, 2–helium, 3–barometer, 4– .5, 5–radiation, 6–180 degrees, 7–molecule, 8–hard water, 9–copper, 10–sodium nitrite and ammonium chloride.

Part D.

1–b, 2–a, 3–c, 4–d, 5–a.

Part E.

1–c and e.

Part F.

1—Correct.

2—100 lbs.

3—The piston valve should be closed.

4—The flow should be in the opposite direction.

5—The water in the trap is omitted.

Maximum Credit—37 points.

Scoring Key for General Science Examination

New 3

Part A.

1–true, 2–false, 3–false, 4–true, 5–false, 6–true, 7–false, 8–true, 9–false, 10–true.

Part B.

1–500 lbs., 2–potassium chlorate and manganese dioxide, 3–15 lbs. to the square inch, 4–18.4 grams, 5–240,000 miles, 6–250 ft. lbs.

Part C.

1–star, 2–eclipse of moon, 3–dew point, 4–friction, 5–distillation, 6–ampere, 7–conduction, 8–carbon dioxide.

Part D.

1–a, 2–b, 3–d, 4–c, 5–a, 6–c.

Part E.

1–a and d, 2–b and c.

Part F.

1. There should be twice as much hydrogen collected over the negative pole or electrode as oxygen collected over the positive pole or electrode. Hydrogen is liberated over the cathode and oxygen over the anode.
2. Water should be coming out of all the openings in streams of approximately equal sizes.
3. The filament is omitted in the incandescent lamp.
4. Unlike poles should be attracted and like poles repelled.
5. Correct.

Maximum Credit—39 points.

Scoring Key for General Science Examination

New 4

Part A.

1–true, 3–true, 3–false, 4–true, 5–false, 6–false, 7–true, 8–false, 9–false, 10–true.

Part B.

1–600 lbs., 2–19.5 inches, 3–104 degrees F., 4–60 degrees C., 5–73%.

Part C.

1–cyclone, 2–evaporation, 3–thermometer, 4–four miles, 5–conduction.

Part D.

1 and 5.

Part E.

1–c, 2–a, 3–d, 4–b, 5–c, 6–a, 7–d, 8–b.

Part F.

1. Arrows representing direction of convection currents produced are omitted.
2. Correct.
3. There should be 30 inches between the level of the mercury in the tumbler to the level of the mercury in the barometer tube.

4. In the high area the direction of the winds should be spirally directed outward from the center.

Maximum Credit—34 points.

Scoring Key for General Science Examination

New 5

Part A.

1–false, 2–true, 3–false, 4–false, 5–false, 6–true, 7–true, 8–false, 9–true, 10–true.

Part B.

1–15.5 degrees C (15 5/9 degrees C or 16 degrees C.).

2–.5 gram per c.c. (or ½ gram per c.c.), 3–72 lbs. per sq. in., 4–5136 grams, 5–500 lbs., 6–360 ft. lbs., 7–4 lbs., 8–18.4 grams, 9–72 grams, 10–6 strands of rope.

Part C.

1–mixture of gases, 2–physical change, 3–efficiency, 4–potassium chlorate and manganese dioxide, 5–filtration, 6–30 ft., 7–distillation, 8–barometer.

Part D.

3.

Part E.

1–a, 2–b, 3–d, 4–c.

Part F.

1. The force is equal to 100 lbs.
2. The cylinder valve should be open and the piston valve should be closed.
3. The tube on the right in the flask is too long, and on the left, too short. (Changing the direction of the arrows and making the tube on the right of the expansion tank short and the tube on the left side longer is also correct.)
4. The fulcrum is the part of the hammer touching the wall, the force is at the end of the handle and the nail is the resistance.
5. Correct.

Maximum Credit—38 points.

Scoring Key for General Science Examination

New 6

Part A.

1–true, 2–false, 3–false, 4–true, 5–false, 6–false, 7–false, 8–true, 9–true, 10–true.

Part B.

1–180 degrees, 2–75%, 3–360 lbs., 4–150 ft. lbs., 5–5%, 6–165,000 ft. lbs., 7–100 grams, 8–0.8 gram per c.c., 9–12 lbs., 10–750 lbs.

Part C.

1–a molecule, 2–carbon dioxide, 3–star, 4–silver, 5–fair weather, 6–eclipse of the sun, 7–steam engine, 8–tungsten, 9–4 degrees C., 10–zinc cup.

Part D.

3.

Part E.

1–b, 2–c, 3–a, 4–d, 5–b.

Part F.

1. The third cell should have the relative position of the positive pole and the negative pole reversed.
2. There should be a vacuum between the double walls of the glass flask.
3. 150 lbs.
4. O.K.
5. Force-looped handles, fulcrum-pivot at crossing, resistance-termination of inner sharpened edges of crossed blades.

Maximum Credit—41 points.

Section 5

Scores in Tests given to General Science Classes February to June 1922

Student	*Terman*	*Army A*	*New 1*	*Ord. 1*	*New 2*	*Ord. 2*	*New 3*	*Ord. 3*
1	130	122	10	25	18	...	19	...
2	71	...	10	8	17	10	...	15
3	142	100	20	32	30	26	29	27
4	47	44	11	11	...	20	9	5

Student	*Ter-man*	*Army A*	*New 1*	*Ord. 1*	*New 2*	*Ord. 2*	*New 3*	*Ord. 3*
5	95	80	6	32	20	24	14	10
6	82	99	11	33	...	28	22	16
7	109	87	7	36	...	20	19	27
8	109	...	14	28	...	...	...	...
9	83	96	6	...	17	20	23	20
10	92	63	9	20	...	2	...	...
11	147	...	19	21	28	36	25	30
12	124	124	...	20	20	14	14	37
13	74	85	11	27	14	16	25	28
14	118	102	26	33	...	28	28	38
15	91	...	5	20	11	28	16	30
16	105	83	16	29	18	14	20	25
17	110	112	17	26	22	14	13	..
18	110	87	23	41	24	28	23	34
19	131	106	17	32	30	16	20	38
20	86	97	2	14	9	6	12	8
21	133	102	7	16	19	20	21	12
22	78	95	21	27	13	26	22	24
23	165	130	23	32	33	30	28	33
24	145	102	9	28	20	14	28	41
25	100	101	15	...	...	14	22	..
26	131	137	7	17	21	20	15	26
27	...	82	19	32	...	...	17	...
28	97	110	13	36	17	36	24	28
29	90	83	16	29	21	32	...	...
30	151	146	16	36	...	...	...	...
31	148	111	13	...	23	24	...	...
32	101	87	12	25	19	20	23	28
33	158	132	19	35	31	36	28	33
34	131	...	19	25	14	24	20	20
35	141	126	9	28	22	36	18	4
36	141	111	22	32	26	38	33	38
37	87	81	14	24	22	28	15	...
38	142	118	22	20	20	10	24	20
39	115	...	17	23	24	36	...	24
40	74	87	10	27	10	24	15	20
41	94	90	15	41	22	36	22	18
42	124	111	14	16	27	18	22	31
43	68	86	8	19	11	18	17	30
44	115	73	5	12	18	22	9	17
45	101	92	14	25	28	24	24	24
46	98	93	16	...	...	26	27	...
47	175	144	21	32	22	26	26	36

Student	*Ter-man*	*Army A*	*New 1*	*Ord. 1*	*New 2*	*Ord. 2*	*New 3*	*Ord. 3*
48	151	144	25	40	25	24	30	42
49	92	65	10	34	25	34	24	26
50	101	...	12	24	...	...	...	...
51	145	128	16	33	26	36	19	37
52	101	88	22	35	29	32	21	26
53	93	96	8	25	18	18	23	23
54	108	120	4	36	17	18	19	...
55	109	91	22	8	21	12	25	...
56	102	...	4	...	11	4	...	...
57	169	138	22	37	26	28	29	44
58	106	127	14	23	12	14	17	32
59	156	139	20	37	24	38	30	38
60	130	96	8	12	14	12	21	25
61	126	98	23	23	13	20	15	12
62	106	84	9	15	15	12	...	27
63	106	90	16	22	15	24	17	19
64	102	87	13	31	17	20	18	23
65	102	93	20	29	23	26	22	28
66	114	111	15	29	22	34	21	30
67	152	124	26	32	31	30	24	46
68	165	131	10	15	20	22	...	37
69	82	91	8	25	10	8	13	21
70	100	80	10	12	13	8	15	22
71	128	119	15	21	24	26	22	...
72	150	145	17	32	31	34	25	34
73	77	91	14	32	14	22	18	28
74	143	138	22	40	24	26	28	41
75	125	102	9	25	19	30	20	32
76	88	91	11	12	21	18	23	16
77	70	73	13	16	11	6	21	23
78	120	96	20	27	22	32	24	31
79	139	135	22	20	28	32	31	34
80	106	122	13	32	25	32	29	25
81	103	119	18	28	26	26	24	14
82	119	121	16	28	24	38	16	28
83	140	107	19	17	20	30	22	24
84	102	100	15	28	20	18	21	31
85	86	...	10	25	...	...	...	...
86	156	141	18	12	22	20	22	32
87	113	111	12	37	29	32	21	28
88	126	97	13	20	18	30	20	22
89	154	110	10	24	20	24	...	22
90	163	129	24	...	29	30	27	20

Student	*Ter-man*	*Army A*	*New 1*	*Ord. 1*	*New 2*	*Ord. 2*	*New 3*	*Ord. 3*
91	162	120	21	16	22	16	20	4
92	110	95	22	33	31	36	20	35
93	136	133	38	...	20	22	...	16
94	122	101	13	24	20	20	15	16
95	87	78	20	27	22	36	27	28
96	78	90	14	24	18	18	19	23
97	124	109	11	29	...	...	...	...
98	163	139	17	28	25	36	25	34
99	112	88	12	14	15	34	19	30
100	155	140	19	31	20	22	23	23
101	124	135	15	12	25	24	17	21
102	102	93	10	16	...	28	13	...
103	101	...	10	32	19	14	...	...
104	156	137	24	31	21	26	27	38
105	139	122	14	36	25	22	18	...
106	111	122	7	25	24	24	20	12
107	144	...	17	32	28	...	...	...
108	95	97	...	...	12	...	8	...
109	119	108	17	32	13	22	16	24
110	170	139	19	20	30	22	21	22
111	102	101	15	25	26	12	19	28
112	128	114	14	20	22	32	29	20
113	143	116	...	...	...	...	...	...
114	89	106	10	30	10	34	24	20
115	104	92	6	25	16	20	23	21
116	101	98	2	32	23	30	18	16
117	139	128	...	31	16	24	...	...
118	109	79	16	15	22	24	24	19
119	84	74	14	25	23	14	22	...
120	150	126	20	16	23	30	27	27
121	170	143	27	24	25	28	26	27
122	94	79	15	27	14	22	22	37
123	86	68	14	26	19	16	22	17
124	114	111	...	21	17	24	12	14
125	89	13	31	...	...	...	...	15
126	104	85	17	14	20	10	17	25
127	160	116	13	17	19	34	27	14
128	90	64	13	24	16	...	12	13
129	85	77	13	32	14	26	24	23
130	...	61	10	27	22	42	24	29
131	117	99	23	35	24	36	31	40
132	131	90	15	20	23	22	27	36
133	126	85	20	28	21	24	28	34

Student	*Ter-man*	*Army A*	*New 1*	*Ord. 1*	*New 2*	*Ord. 2*	*New 3*	*Ord. 3*
134	145	115	22	45	24	40	30	40
135	86	81	19	23	22	20	23	29
136	167	167	20	32	27	...	...	...
137	130	116	19	28	22	32	22	32
138	...	91	7	21	14	26	15	32
139	138	114	18	28	26	36	22	30
140	80	...	8	24	...	...	...	...
141	106	111	8	13	14	8	14	23
142	157	...	17	20	...	...	...	...
143	152	142	16	24	21	26	27	36
144	142	119	15	23	25	18	22	17
145	85	91	13	13	25	28	25	21
146	102	67	16	27	20	22	24	21
147	126	136	10	24	20	22	25	30
148	131	91	21	41	22	20	29	46
149	160	113	21	17	24	28	29	37
150	99	88	9	27	19	18	16	16
151	156	123	9	12	14	20	...	27
152	...	143	14	18	24	32	23	35
153	181	165	...	...	26	32	...	34
154	101	...	15	31	...	...	...	...
155	102	81	5	16	13	10	18	24
156	185	153	20	32	27	26	25	40
157	154	139	23	31	30	16	29	40
158	152	138	...	28	21	38	...	44

Scores in Tests given to General Science Classes
September 1922 to January 1923

Student	*Ter-man*	*Army A*	*New 4*	*Ord. 4*	*New 5*	*Ord. 5*	*New 6*	*Ord. 6*
201	...	137	19	...	...	17	...	29
202	167	139	20	24	26	22	25	21
203	142	133	13	13	15	23	20	21
204	119	97	28	24	23	21	28	22
205	184	154	25	25	35	33	30	36
206	106	80	15	11	16	14	19	21
207	147	90	20	14	24	28	23	18
208	121	...	26	23	...	...	...	...
209	162	132	26	33	29	29	30	35
210	137	100	15	19	22	18	20	16
211	140	99	12	16	25	20	19	27
212	151	104	19	19	23	22	22	25
213	194	132	22	33	23	34	26	22

Student	*Ter-man*	*Army A*	*New 4*	*Ord. 4*	*New 5*	*Ord. 5*	*New 6*	*Ord. 6*
214	119	86	5	9	19	12	15	11
215	160	104	15	10	22	11	22	...
216	165	115	17	17	24	23	23	24
217	100	89	14	15	16	11	...	...
218	158	127	18	23	24	21	25	18
219	166	127	18	25	25	22	22	22
220	154	140	27	30	28	21	26	33
221	130	82	15	10	24	23	26	26
222	172	117	24	26	28	22	26	20
223	150	108	13	11	21	14	...	...
224	175	158	16	23	24	24	...	24
225	183	142	29	18	22	27	28	26
226	115	73	17	13	14	18	12	11
227	86	39	16	17	13	8	14	11
228	181	145	23	31	28	34	34	38
229	113	92	17	17	22	23	17	20
230	159	117	24	24	31	31	29	36
231	149	105	21	20	28	30	25	28
232	202	149	29	30	30	30	35	32
233	147	131	14	14	22	23	24	16
234	170	125	21	13	29	22	19	20
235	121	103	18	15	24	22	...	...
236	112	86	13	17	17	24	16	17
237	123	89	20	19	20	13	15	25
238	156	92	21	18	25	15	14	27
239	181	125	20	22	25	18	27	27
240	174	132	22	30	28	27	25	30
241	143	121	8	6	17	14	13	15
242	116	103	19	2	...	...	...	...
243	122	92	18	18	26	22	21	22
244	133	116	17	12	17	15	21	20
245	147	111	19	15	18	21	20	22
246	179	132	22	22	25	27	25	23
247	108	78	13	16	17	7	16	...
248	86	61	...	...	...	...	...	...
249	161	131	25	27	28	25	29	30
250	136	118	21	11	26	24	28	24
251	112	113	15	15	19	5	19	19
252	163	111	13	16	19	11	17	18
253	109	69	15	7	25	25	22	21
254	173	123	23	31	27	33	21	22
255	191	131	23	24	27	29	32	30
256	152	109	20	20	29	27	23	...

Student	*Ter-man*	*Army A*	*New 4*	*Ord. 4*	*New 5*	*Ord. 5*	*New 6*	*Ord. 6*
257	128	89	15	15	27	27	24	27
258	154	120	23	26	24	22	27	27
259	189	154	20	24	26	22	25	31
260	193	129	21	33	30	31	34	33
261	119	93	13	15	12	10	12	8
262	164	112	23	25	...	...	...	...
263	94	57	15	19	11	17	13	28
264	181	129	22	32	24	24	33	28
265	178	144	22	30	33	24	22	29
266	161	125	20	24	18	17	18	28
267	160	133	19	25	27	28	26	21
268	102	66	19	20	20	19	22	21
269	172	115	20	29	26	30	18	30
270	186	119	20	26	29	14	29	18
271	101	80	19	26	19	5	...	4
272	121	89	16	9	17	10	...	...
273	116	96	10	5	9	6	10	10
274	115	97	22	22	16	13	17	16
275	156	127	19	25	22	11	20	24
276	144	114	21	29	21	23	24	31
277	167	139	18	24	22	15	29	15
278	146	122	26	24	20	13	17	11
279	172	108	20	29	26	22	17	26
280	108	90	16	18	18	10	...	...
281	98	83	18	19	23	11	19	10
282	182	131	26	27	31	33	30	38
283	163	115	22	25	21	22	32	28
284	159	100	...	15	17	9	15	12
285	115	69	18	21	19	19	16	14
286	84	92	15	11	12	5	...	12
287	141	93	18	32	17	6	12	19
288	109	75	15	13	15	21	18	23
289	175	137	23	31	25	34	22	33
290	118	93	16	13	12	18	15	17
291	127	93	25	19	22	24	20	16
292	100	95	18	8	23	17	...	32
293	112	75	17	20	10	8	...	...
294	139	94	20	19	26	9	19	25
295	77	76	9	11	12	11	9	...
296	151	127	21	31	24	27	26	32
297	137	106	14	28	15	23	20	15
298	167	122	...	...	...	...	...	...
299	...	85	8	14	...	...	...	...

Student	*Ter-man*	*Army A*	*New 4*	*Ord. 4*	*New 5*	*Ord. 5*	*New 6*	*Ord. 6*
300	133	101	13	13	22	16	22	21
301	155	108	19	28	23	22	22	29
302	144	...	11	3	...	...	...	...
303	164	136	19	29	20	18	21	23
304	148	111	15	20	18	19	18	8
305	100	66	21	21	16	19	25	12
306	181	114	24	20	20	27	26	25
307	117	74	9	...	13	5	...	5
308	143	107	16	23	24	13	18	18
309	96	80	8	9	...	...	15	...
310	125	89	9	17	23	20	17	14
311	147	117	28	30	25	24	27	32
312	106	81	17	20	17	12	25	18
313	160	124	30	31	27	22	25	10
314	143	110	27	24	29	19	27	19
315	105	97	27	19	22	22	20	20
316	120	85	19	25	26	31	24	24
317	140	91	20	11	24	18	21	10
318	166	110	16	20	21	28	24	31
319	106	58	19	18	12	14	14	10
320	125	87	21	20	27	25	27	21
321	68	62	9	10	10	16	...	...
322	156	82	21	27	25	22	...	...
323	92	131	...	...	...	...	...	...
324	153	130	18	23	21	16	17	24
325	122	94	18	30	25	19	22	...
326	149	107	12	17	14	10	13	11
327	139	82	15	27	26	30	14	29
328	115	101	15	5	13	12	15	15
329	140	121	13	21	17	11	18	16
330	138	81	14	11	...	...	...	...
331	144	110	22	24	22	19	24	19
332	168	141	18	17	...	...	...	...
333	181	137	22	29	28	37	30	31
334	175	134	15	28	23	18	25	18
335	118	102	12	...	19	11	18	9
336	126	77	15	18	24	28	28	27
337	172	132	30	32	34	35	32	31

BIBLIOGRAPHY

1. Albright, G. H. How Teachers Mark, School and Society, 3: 462-7, March 25, 1916.
2. Armstrong, J. E. Variation in Grading High School Pupils. Chicago Schools Journal, 4: 346-8, May, 1922.
3. Ballard, P. B. Group Tests of Intelligence. London: Hodder and Stoughton, 1922.
4. Beeson, M. F. School Marks in the High School. Educational Administration and Supervision, 7: 380-7, October, 1921.
5. Bell, J. C. A Test in First Year Chemistry. The Journal of Educational Psychology, 9: 199-209, April, 1918.
6. Bird, G. E. A Test of Some Standard Tests, The Journal of Educational Psychology, 11: 275-83, May-June, 1920.
7. Book, W. F.: The Intelligence of High School Seniors. New York: The Macmillan Company, 1922.
8. Boring, E. G. The Logic of the Normal Law of Error in Mental Measurement. The American Journal of Psychology, 31: 1-33, January, 1920.
9. ————————. The Marking System in Theory. Pedagogical Seminary, 21: 269-77.
10. Breed, F. S. Shall We Classify Pupils by Intelligence Tests? School and Society, 15: 406-9, April 15, 1922.
11. Breed, F. S. and Breslich, E. R. Intelligence Tests and the Classification of Pupils, Part I and Part II. The School Review, 30: 51-66 and 210-216, January and March, 1922.
12. Bright, I. J. The Intelligence Examination for High School Freshmen. Journal of Educational Research, 4: 44-55, June, 1921.
13. Brooks, S. S. Measuring the Progress of Pupils by Means of Standardized Tests. Journal of Educational Research, 4: 161-72, October, 1921.
14. Brown, W. The Essentials of Mental Measurement. Cambridge: at the University Press, 1911.
15. ————————. Some Experimental Results in the Correlation of Mental Abilities. The British Journal of Psychology, 3: 296-322, 1909-1910.
16. Cajori, J. A New Marking System and Means of Measuring Mathematical Abilities. School Science and Mathematics, 14: 283-93, April, 1914.
17. Camp, F. S. Some "Marks." An Administrative Problem. The School Review, 25: 697-713, December, 1917.

18. Camp, H. L. Scales for Measuring the Results of Physics Teaching. Journal of Educational Research, 5: 400-5, May, 1922.
19. ————————. Scales for Measuring Results of Physics Teaching. University of Iowa Studies in Education, Volume 2, Number 2, October 1, 1921.
20. Capen, S. P. Accredited Secondary Schools in the United States. U. S. Bureau of Education, Bulletin, 1915, No. 7.
21. Capps, A. G. The Functions of Tests and Scales as Found in Recent Educational Literature. Journal of Educational Research, 6: 204-8, October, 1922.
22. Chambers, G. G. A Study of the Reliability of Test Questions. The Mathematics Teacher, 7: 89-100, March, 1915.
23. Chapman, J. C. The Unreliability of the Difference Between Intelligence and Educational Ratings. The Journal of Educational Psychology, 14: 103-8, February, 1923.
24. ————————. The Measurement of Physics Information. The School Review, 27: 748-56, December, 1919.
25. Charters, W. W. Constructing a Language and Grammar Scale. Journal of Educational Research, 1: 249-57, April, 1920.
26. Colvin, S. S. The Use of Intelligence Tests, Educational Review, 62: 134-48, September, 1921.
27. ————————. The Present Status of Mental Testing. Educational Review, 64: 320-37, November, 1922.
28. ———————— and Allen, R. D. Mental Tests and Linguistic Ability. The Journal of Educational Psychology, 14: 1-20, January, 1923.
29. Courtis, S. A. The Gary Public Schools. The Measurement of Classroom Products. New York: General Education Board, 1919.
30. Cummins, R. A. Educational Measuring Sticks and their Uses. American School Board Journal, 63: 33-5, August, 1921.
31. Davis, H. Army Alpha and Students' Grades, Illustrating the Value of the Regression Equation. School and Society, 14: 223-7, September 24, 1921.
32. Dearborn, W. F. School and University Grades, Bulletin of the University of Wisconsin, No. 368: High School Series, No. 9, June, 1910.
33. ————————. The Misuse of Standard Tests in Education. School and Society, 3: 493-5, April 1, 1916.
34. Douglass, H. R. Some Uses and Limitations of the Standard Educational Test, Educational Administration and Supervision, 5: 475-90, November, 1919.
35. ———————— and Spencer, P. L. Is it necessary to Weight Exercises in Standard Tests? The Journal of Educational Psychology, 4: 109-112, February, 1923.
36. Downing, E. R. A Range of Information Test in Science, School Science and Mathematics, 19: 228-33, 1919.

37. ————————. The Range of Information Test in Science Revised. School Science and Mathematics, 20: 77-83, 1920.
38. Educational Events. Experimenting with the New Type of Examination at Columbia. School and Society, 15: 141-2, February 4, 1922.
39. Fee, I. B. Advantages and Disadvantages of Mental Tests. The American Board Journal, 61: 29-30, August, 1920.
40. Finkelstein, I. E. The Marking System in Theory and Practice. Educational Psychology Monographs, No. 10. Baltimore: Warwick and York, 1913.
41. Foster, W. T. Scientific Versus Personal Distribution of College Credits. The Popular Science Monthly, 78: 388-408, April, 1911.
42. Fourteenth Census of the United States, 1920. Volume 1, Population. Table 51. Incorporated Places. Department of Commerce, Bureau of the Census. Washington: Government Printing Office, 1921, pp. 178-319.
43. Franzen, R. The Accomplishment Ratio. Teachers College, Columbia University Contributions to Education, No. 125, New York: Teachers College, Columbia University, 1922.
44. Frasier, G. W. Educational Measurements, The American School Board Journal, 60: 23-4, January, 1920.
45. Freeman, F. W. Experimental Education. Boston: Houghton Mifflin Company, 1916.
46. ————————. Mental Tests. The Psychological Bulletin, 17: 353-62, November, 1920.
47. Gates, A. I. True-False Test as a Measure of Achievement in College Courses. Journal of Educational Psychology, 12: 276-87, May, 1921.
48. ————————. The Correlations of Achievement in School Subjects with Intelligence Tests and Other Variables. The Journal of Educational Psychology, 13: 129-139, and 277-85, March and May, 1922.
49. Geyer, D. L. The Reliability of Rankings by Group Intelligence Tests. The Journal of Educational Psychology, 13: 43-49, January, 1922.
50. ————————. Can We Depend upon the Results of Group Intelligence Tests? Chicago Schools Journal, 4: 203-210 and 245-53, February and March, 1922.
51. Glenn, E. R. The Conventional Examination in Chemistry and Physics Versus the New Types of Tests. School, Science and Mathematics, 21: 666-670 and 746-756, October and November, 1921.
52. Gray, C. T. Variations in the Grades of High School Pupils. Educational Psychology Monographs, No. 8, Baltimore: Warwick and York, 1913.
53. Grier, N. M. The Range of Information in Biology, I. Physiology, II. Zoology, III. Botany. Journal of Educational Psychology 9: 210-17 and 388-92, 10: 509-516, April and September, 1918, December, 1919.

54. Haggerty, M. E. Recent Developments in Measuring Human Capacities. Journal of Educational Research, 3: 241-253, April, 1921.
55. ————————. Educational Measurement and the Teaching of Science. School Science and Mathematics, 23: 103-111, February, 1923.
56. Hall, W. S. A Guide to the Equitable Grading of Students. School Science and Mathematics, 6: 501-10, 1906.
57. Henmon, V. A. C. The Measurement in Intelligence. School and Society, 13: 151-58, February 5, 1921.
58. Herring, J. P. Measurements of Some Abilities in Scientific Thinking. The Journal of Educational Psychology, 9: 535-58, December, 1918.
59. ————————. Derivation of a Scale to Measure Abilities in Scientific Thinking. The Journal of Educational Psychology, 10: 417-432, November, 1919.
60. Holley, C. E. Mental Tests for School Use. The University of Illinois Bulletin, Vol. 17, No. 28, Bureau of Educational Research, Bulletin No. 4, 1920.
61. Holmes, H. W. The General Philosophy of Grading and Promotion in Relation to Intelligence Testing. School and Society, 15: 457-61, April 29, 1922.
62. Hopkins, L. T. The Marking System of the College Entrance Examination Board. Harvard Monographs in Education, Series, 1, No. 2, Cambridge: The Graduate School of Education, Harvard University, October, 1921.
63. Inglis, A. J. Variability of Judgments in Equating Values in Grading. Educational Administration and Supervision, 2: 25-30, January, 1916.
64. ————————. Principles of Secondary Education, Boston: Houghton Mifflin Company, 1918.
65. Intelligence and its Measurement: A Symposium. The Journal of Educational Psychology, 12: 123-147, 195-216, 271-5, March, April and May, 1921.
66. Intelligence Tests and their Use. The Twenty-First Yearbook of the National Society for the Study of Education. Bloomington: Public School Publishing Company, 1922.
67. Jordan, A. M. Correlations of Four Intelligence Tests with Grades. The Journal of Educational Psychology, 13: 419-29, October, 1922.
68. Jordan, R. H. Variation of Marking Systems as Diagnosed by Objective Tests. Journal of Educational Research, 4: 173-79, October, 1921.
69. Jones, E. S. The Influence of Age and Experience on Correlations Concerned with Mental Tests. Baltimore: Warwick and York, 1917.
70. Kelley, T. L. The Reliability of Test Scores. Journal of Educational Research, 3: 370-79, May, 1921.
71. Kelly, F. J. Teachers' Marks. Their Variability and Standardization. Teachers College, Columbia University Contributions to

Education, No. 66, New York: Teachers College, Columbia University, 1914.

72. King, L. A. A Comparative Study of Four Group Intelligence Tests to Determine Their Reliability for Practical Use. Eighth Annual Schoolmen's Week Proceedings, Philadelphia: University of Pennsylvania, 1921, pp. 78-92.
73. Knight, F. B. Data on the True-False Test as a Device for College Examination. The Journal of Educational Psychology, 13: 75-80, February, 1922.
74. Lindsay, M. D. and Gamsby, R. S. Where Test Scores and Teachers' Marks Disagree, The School Review, 29: 569-687, November, 1921.
75. McCall, W. A. A New Kind of School Examination. Journal of Educational Research, 1: 33-46, January, 1920.
76. ————————. Correlation of Some Psychological and Educational Measurements. Teachers College, Columbia University Contributions to Education, No. 79, New York: Teachers College, Columbia, University, 1916.
77. ————————. How to Measure In Education. New York: The Macmillan Company, 1922.
78. Madsen, I. N. Relationship between General Intelligence and Success in Certain High School Subjects. Journal of Educational Research, 3: 396-8, May, 1921.
79. ————————. Interpreting Achievement in School in Terms of Intelligence. School and Society, 14: 59-60, July 30, 1921.
80. ————————. Intelligence and Accomplishment, Educational Administration and Supervision, 9: 17-23, January, 1923.
81. Mead, A. R. Tendencies in Educational Measurements. Educational Review, 61: 117-127, February, 1921.
82. Meyer, M. The Grading of Students. Science N. S. 28: 243-50, August, 1908.
83. Monroe, W. S. The Description of the Performances of Pupils on Exercises of Varying Difficulty, School and Society, 15: 341-3, March 25, 1922.
84. ————————. An Introduction to the Theory of Educational Measurements. Boston: Houghton Mifflin Company, 1923.
85. O'Brien, F. P. The High School Failures. Teachers College, Columbia University Contributions to Education, No. 102, New York: Teachers College, Columbia University, 1919.
86. Otis, A. S. Group Intelligence Tests: Their Value and Limitations. Ninth Annual Schoolmen's Week Proceedings, Philadelphia: University of Pennsylvania, 1922, pp. 55-67.
87. Pickell, F. G. Distribution of Teachers' Marks. Indiana University Bulletin, Vol. 13, No. 2, Bloomington: The Extension Division of Indiana University, October, 1915.

88. Pintner, R. and Paterson, D. G. A Scale of Performance Tests. New York: Appleton and Company, 1917.
89. Powers, S. R. The Achievement of High School and Freshman College Students in Chemistry. School Science and Mathematics, 21: 366-77, April, 1921.
90. Pressey, S. L. An Attempt to Measure the Comparative Importance of General Intelligence and Certain Character Traits in Contributing to Success in School. Elementary School Journal, 21: 220-9, November, 1920.
91. Proctor, W. M. The Use of Intelligence Tests in the Educational Guidance of High School Pupils. School and Society, 8: 473-78 and 502-9, October 19, and October 26, 1918.
92. ————————. Psychological Tests as a Means of Measuring the Probable School Success of High School Pupils. Journal of Educational Research, 1: 258-70, April, 1920.
93. ————————. Psychological Tests and Guidance of High School Pupils. Journal of Educational Research Monographs, No. 1, Bloomington: Public School Publishing Company, June, 1921.
94. Pyle, W. H.: The Psychology of Learning. Baltimore: Warwick and York, 1921.
95. Rivett, B. J. Results with Standard Chemistry Tests. School Science and Mathematics, 21: 720-22, November, 1921.
96. Roback, A. A. Subjective Tests versus Objective Tests. Journal of Educational Psychology, 12: 439-344, November, 1921.
97. Rogers, A. L. Intelligence Tests and Educational Progress. Educational Review, 61: 110-116, February, 1921.
98. Ruch, G. M. A Study of the Mental, Pedagogical and Physical Development of the Pupils of the Junior Division of the University High School, Eugene, Oregon. University of Oregon Publication Vol. 1, No. 7, September, 1920.
99. Rugg, H. O. Teachers' Marks and Marking Systems. Educational Administration and Supervision, 1: 117-42, February, 1915.
100. ————————. Statistical Methods Applied to Education, Boston: Houghton Mifflin Company, 1917.
101. Rusk, R. R. Introduction to Experimental Education. New York, Longmans, Green and Company, 1913.
102. Simpson, B. R. Correlations of Mental Abilities, Teachers College, Columbia University Contributions to Education, No. 53. New York: Teachers College, Columbia University, 1912.
103. Spearman, C. General Intelligence Objectively Determined and Measured. The American Journal of Psychology, 15: 201-293, 1904.
104. Starch, D. Reliability and Distribution of Grades, Science, N. S. 38: 630-36, October, 1913.
105. ————————. Can the Variability of Marks be Reduced? School and Society, 2: 242-3, August 14, 1915.

106. ————————. Experiments in Educational Psychology (Revised). New York: The Macmillan Company, 1917.
107. ————————. Educational Psychology, New York: The Macmillan Company, 1919.
108. ———————— and Elliott, E. C. Reliability of Grading Work in English, The School Review, 20: 442-457, September, 1912.
109. ————————. Reliability of Grading Work in Mathematics. The School Review, 21: 254-59, April, 1913.
110. ————————. Reliability of Grading Work in History. The School Review, 21: 676-81, December, 1913.
111. Steele, A. G. Training Teachers to Grade. Pedagogical Seminary, 18: 523-32, 1911.
112. Terman, L. M. The Intelligence of School Children. Boston: Houghton Mifflin Company, 1919.
113. ————————. The Use of Intelligence Tests in the Grading of School Children, Journal of Educational Research, 1: 20-32, January, 1920.
114. ———————— and others. Intelligence Tests and School Reorganization. Yonkers: World Book Company, 1922.
115. The Measurement of Educational Products. The Seventeenth Year book of the National Society for the Study of Education, Part II. Bloomington: Public School Publishing Company, 1918.
116. Thompson, J. E. Educational Measurements, School and Home Education, 36: 70-72. November, 1916.
117. Thorndike, E. L. An Introduction to the Theory of Mental and Social Measurements. New York: Teachers College, Columbia University, 1913.
118. ————————. Educational Psychology, Vol. I Mental Work and Fatigue and Individual Differences and Their Causes, Vol. II. The Original Nature of Man, Vol. III, The Psychology of Learning, New York: Teachers College, Columbia University, 1913, 1914.
119. ————————. Tests of Intelligence. Reliability, Significance, Susceptibility to Special Training and Adaptation to the General Nature of the Task. School and Society, 9: 189-95, February 15, 1919.
120. ————————. Reliability and Significance of Tests of Intelligence. The Journal of Educational Psychology, 11: 284-9, May-June, 1920.
121. ————————. Scales and Tests Supersede Old-Fashioned School Marks. Journal of Education, 94: 395-7, October, 1921.
122. ————————. Completion Tests in Physics. School Science and Mathematics, 22: 637-47, October, 1922.
123. Thurstone, L. L. The Predictive Value of Mental Tests. Educational Review, 63: 11-22, January, 1922.
124. Toops, H. A. Trade Tests in Education. Teachers College, Columbia University Contributions to Education, No. 115, New York: Teachers College, Columbia University, 1921.

125. Trabue, M. R. Some Pitfalls in the Administrative Use of Intelligence Tests. Journal of Educational Research, 6: 1-11, June, 1922.
126. Updegraff, H. Educational Measurements. University of Pennsylvania Lectures, Free Public Lecture Course 1917-1918. Philadelphia: University of Pennsylvania, 1918, pp. 89-102.
127. Webb, H. H. A Preliminary Test in Chemistry. The Journal of Educational Psychology, 10: 36-43, January, 1919.
128. Weglein, D. E. The Correlation of Abilities of High School Pupils. Baltimore: The Johns Hopkins Press, 1916.
129. Wells, F. L. The Principle of Mental Tests. Science, 38: 221-4, August 15, 1913.
130. Wells, A. B. Tests in Biology and General Science. School Science and Mathematics, 22: 826-33, December, 1922.
131. Whipple, G. M. Manual of Mental and Physical Tests. Baltimore: Warwick and York, 1914.
132. Wilson, G. M. and Hoke, H. J. How to Measure. New York: The Macmillan Company, 1920.
133. Witmer, L. What is Intelligence and Who Has it? Ninth Annual Schoolmen's Week Proceedings, Philadelphia: University of Pennsylvania, 1922, pp. 45-55.
134. Woodworth, R. S. Psychology: A study of Mental Life. New York: Henry Holt and Company, 1921.
135. Yerkes, R. M. (editor): Psychological Examining in the United States Army. Memoirs of the National Academy of Sciences, Volume 15, Washington: Government Printing Office, 1921.
136. Yoakum, C. and Yerkes, R. M. Army Mental Tests. New York: Henry Holt and Company, 1920.
137. Yocum, A. D. Culture, Discipline and Democracy. Philadelphia: Christopher Sower Company, 1913.